Weeds

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Weeds

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K. P. Buchholtz, *Editor*, Dept. of Agronomy, Univ. of Wisconsin, Madison, Wisconsin.

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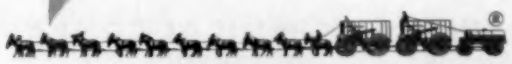

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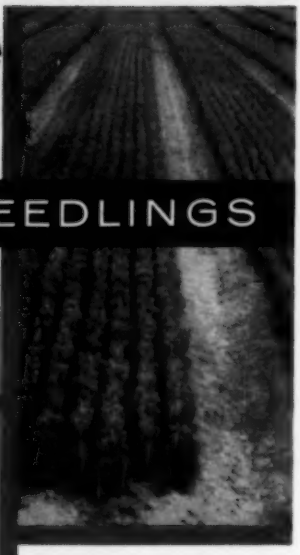

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Weeds

JOURNAL OF THE WEED SOCIETY OF AMERICA

VOLUME 6 JULY 1958 NUMBER 3

Problems, Progress and Organization of Weed Control in Continental Europe[1]

EWERT ÅBERG[2]

At the Third British Weed Control Conference in 1956 I had the pleasure to discuss weed control research and development in Sweden (3). Some of the statements I made at that time will be used as a background to this paper. It was emphasized that there has been continuous change in weed control methods since World War I depending on the introduction of chemical weed killers but also on improved methods for cultivating and using the lands. Use of chemicals have brought with it changes in the weed flora meaning that certain weeds which were not serious in earlier days have now become a menace to the farmers. This brings with it a need for new chemicals with other weed killing properties. But it also brings with it a need for new cultivating methods and a better crop sequence. Cultivated plants are influenced by the chemicals. The effect on the cultivated plants depends on the stage of development of these plants. In uneven fields the harmful effect can be serious as there are always some plants that are sensitive at the time of spraying. The effect of the chemicals may depend on the purity of the acids. In MCPA, for example, the percentage of the 4–isomer, *i.e.* the 2–methyl–4–chlorophenoxyacetic acid, is important. It should be 95 per cent or slightly above as shown by Åberg (1). The after effect of chemicals in the soils may be longer and more severe under northern conditions than under southern. For the choice of crops this must be considered. Thus there is no doubt that today, more than at any earlier period, weed control is a crop production problem. It can not be treated without considering crop production problems. Sometimes there is a feeling over in our part of the world that since the end of World War II chemicals and their properties have been emphasized too much in weed control discussions. Chemicals are, no doubt, important, but they can never get the place they are entitled to, unless our research work in weed control pays attention also to biology and ecology of those plants that we treat; cultivated plants as well as weeds. I believe we are in Europe thinking

[1]Invitational paper presented at the Weed Society of America meeting, Memphis, Tennessee, January 14, 1958.

[2]Institute of Plant Husbandry, Royal Agricultural College, Uppsala 7, Sweden.

more about this particular end of the weed control work than you need to do over here. We usually have small farms with a number of different crops on each one of them. Thus we must learn to apply our chemical weed killers or use our cultivated methods in different ways for each one of these crops. For economical reasons and with regard to the supply of food and feed we need high yields per hectare. Every measure on a farm must be chosen with this in mind. Our problems, progress and organization of weed control must then be seen against the background I have now tried to give you.

As weed control is a crop production problem the stand of cultivated plants and the competition between those plants and weeds become of interest. Farming methods in Europe have been greatly improved during the last two or three decades. Tractors and modern implements are common, high quality fertilizers and seeds are used and good varieties are found on many farms in most of the European countries. Well drained soils make it possible to get good seedbeds and even stand of crops. But for a number of farmers it has not yet become clear that a thick, even and healthy stand of any cultivated crop is the best method of controlling weeds. This must be shown to them with experimental results. The research workers must therefore carry on studies on the competition between cultivated plants and weeds under various conditions. Rademacher and his associates in Stuttgart-Hohenheim have worked on these problems for a number of years. Rademacher (26) has, for example, shown that the number of weeds per square meter decreases from the edge to the inner parts of a cereal field. He found 69 plants per square meter in the first 20 cm of the field, 34 between 20 and 40 cm, 22 between 40 and 60 cm, 12 between 60 and 80, 5 between 80 and 100 cm and from 2 to 4 weeds per square meter from 100 cm and on. In the stand on the outer 20 cm of the field there was between 20 and 50 per cent of the light intensity on an open area outside of the field while in the areas 100 cm or more from the edge there was only 5 per cent. Even if many factors, beside the light, can influence the appearance of weeds Rademacher considers light as a very important one. In one of our own experiments with wild oats, Åberg and Wiberg, (4), it was found in the spring of 1954 that the number of wild oat plants averaged between 384 and 440 in winter rye and between 1024 and 1048 in winter wheat. These observations were made on plots with similar growing conditions. It is true that a number of factors may have had an influence on the number of weeds in these plots, but it can safely be stated that in the stand of winter rye the light intensity was lower than in the stand of winter wheat. Just as light can influence the development of weeds in a stand of cultivated plants other factors like available nutrients, pH-value in the soil, moisture and temperature in the stand can have an influence on the appearance of weeds. How great this influence is under different environmental conditions needs to be investigated further.

As we are in Europe highly dependent on thick and well developed stands of our cultivated plants there is an increasing interest and a real need for studies of plant associations on arable lands, *i.e.* associ-

ations of weeds and cultivated plants. Considering the steadily increasing use of chemical weed killers such studies must, however, be carried out not only in unsprayed fields but also in fields treated with different chemicals. Such studies should clarify the competitive effect of different weeds and cultivated plants under various environmental conditions. Competition studies should emphasize especially the behavior of those weed species we do not know how to control. Granström (12) reported briefly on a competition study which will later be published in detail.[3] In this investigation the competition between lambsquarters (*Chenopodium album* L.), charlock (*Sinapis arvensis* L.) and wild oats (*Avena fatua* L.) on one side and different crops (barley, oats, wheat, peas and seed flax) on the other, was studied in field trials and pot experiments at the Institute of Plant Husbandry in Uppsala from 1952 to 1955. It was found that of the three species mentioned wild oats has the strongest ability to compete with the crops mentioned. It can, better than the other two weed species, utilize a supply of nitrogen in competition with cultivated plants. Of the cereals mentioned barley has the strongest competitive ability against wild oats. Barley had a good competitive ability against lambsquarters when there were 200 barley plants per square meter. With peas 175 plants per square meter, and with seed flax 1000 plants per square meter, were needed for good competition against lambsquarters. The competitive ability of barley and seed flax was increased after fertilizing with nitrogen except in the case of seed flax in competition with wild oats. The competitive ability of peas was not changed by nitrogen application. From his experiments Granström concludes that the most reliable way to improve the competitive ability of a crop is to increase its plant density.

In the discussion on competition between crops and weeds the role of root exudates for plant growth and competition between plants has again been taken up for investigations. Osvald (23) pointed out that a great deal of experimental work is required to elucidate the problem of experimental antagonism or the degree of compatibility of the plants. He did it on basis of observations in Swedish experiments. Grümmer (13) has worked in this particular field and is of the opinion that certain substances from a plant can influence the development of another plant in such a way that this can be of importance for the competition between the plants. In 1957 Grümmer (14) reported that false flax (*Camelina* spp.) in a flax field can lower the yield of the flax even though it does not have a very good competitive ability. Grümmer found that root exudates were not important in this particular case; but substances from the leaves of false flax which fell on the soil, had an adverse effect on the flax plants. The effect of substances like the ones mentioned by Osvald and Grümmer should be studied further and the substances isolated and identified. Much remains to be done in this field. Kommedahl (19) pointed out, on basis of studies in this country, that quackgrass can be toxic to crop seedlings. According to him rhizomes, foliage

[3]In the Annals of the Royal Agricultural College of Sweden, Uppsala.

and seeds of quackgrass can be toxic to crop seedlings. Of special interest to us is that Kommedahl also pointed out that the rhizomes of quackgrass may harbor disease organisms which attack crop seedlings. The whole discussion on the effect of toxic substances from one plant species on the growth of another plant species is an intricate one. Börner (9) pointed out from his work at Stuttgart-Hohenheim that substances given off from roots and seeds of a plant are not responsible for the competitive effect of plant species. Only substances given off from the leaves are important for the competition. At the same time, however, Börner emphasizes that those residues from the plants, which stay in or on the soil after harvest, may give rise to substances with physiological effect. It still remains to be shown, however, if these substances are effective enough to influence the growth of plants directly. Do they, possibly, have an influence only through changes in the microflora? In areas of Europe where the breaking down of the crop residues may take a long time due to cold and long winters factors like the ones mentioned need to be studied further. The fact that we may also change the chemical composition of certain parts of weed or crop plants by spraying with growth regulating substances now used for weed killing purposes makes this whole question even more interesting. Some recent Swedish studies on this particular question will be discussed after the presently used chemical weed killers have been treated.

Since selective weed killers of the chlorinated phenoxyacetic acid type came on the market immediately after World War II they have been closely observed in Europe. The general situation seems to be that MCPA is the weed killer for cereals, flax and potatoes etc. while 2,4–D, (2,4–dichlorophenoxyacetic acid) is the weed killer on grasslands, in grass seed production fields etc.

Although the general rule seems to be that 2,4–D is more effective against weeds than MCPA there is evidence, Vidme (34), Hagsand and Åberg (15), that MCPA is more effective than 2,4–D against hempnettle (*Galeopsis* spp.) and corn spurrey (*Spergula arvensis* L.). In German experiments by Schmidt (29) it has been shown that there are definite differences in the effects of MCPA and 2,4–D on a number of weeds. Such results are of interest because they have given rise to discussions on the importance of the relationship between growth-regulating weed killers applied to the plants and natural hormones produced inside the plants as well as to the effect of these weed killers on the enzyme systems of plants. In neither of these cases is there enough known at present, and further investigations are necessary.

When weed killers of the chlorinated phenoxyacetic acid type have been used for a number of years there can be noted a change in the weed flora meaning that weeds that are resistant or slightly susceptible to MCPA or 2,4–D increase in numbers. Cleavers (*Galium aparine* L.), sowthistles (*Sonchus* spp.) and scentless mayweed (*Matricaria inodora* L.) can be cited as good examples of weeds that have resisted the phenoxyacetic acids enough to increase in numbers. It has been pointed out earlier, Åberg (2), that weed killers with very

specialized properties are needed. To a certain extent dinitrobutylphenols can be useful. They are also applied in Europe as complements to the phenoxyacetic acids either in alternation with phenoxyacetic acids or in mixture with them. Dinitroorthocresols are used in the same way. But this is not an ideal solution of the problem as both butylphenols and orthocresols are more difficult to use than phenoxyacetic acids and similar ones. For an effective control of weeds, such as the three species mentioned a few minutes ago, there has been a search for new substances. For cleavers and the closely related hedge bedstraw (*Galium mollugo* L.) 2–(2–methyl–4–chlorophenoxy) propionic acid has proven to be useful. It may be useful against other weeds too, for example chickweed (*Stellaria media* Cyr.). Against cleavers Pfeiffer (25) reports good effect from a mixture of 2,3,6–trichlorobenzoic acid and MCPA. According to Pfeiffer such a mixture can be used also against mayweeds, coltsfoot and redshank. Against *Sonchus* spp. 4–(2–methyl–4–chlorophenoxy)butyric acid may be applied. Its possibilities against a number of other weeds seem, however, to be limited. Apparently it is not in general use comparable to the phenoxyacetic acids. Instead it appears to be a weed killer with a very specialized effect and useful mainly in legumes and undersown cereals.

There is as yet no real good weed killer against scentless mayweed. Is it coming? We hope so because a chemical keeping scentless mayweed under control, for example in red clover, would be very welcome.

The possibilities for getting new chemicals are fair as long as we deal with dicotyledonous weeds but become much worse when we turn to monocotyledons. I have chosen to show this with problems relating to wild oats, quackgrass and loose silky bent. We know from our experiments that IPC (isopropyl N-phenylcarbamate) and CDAA (2–chloro–N, N–diallylacetamide) have an effect on wild oats. But it is also clear that the effect of these chemicals depends to a very high extent on the environmental conditions at the time of application. Especially in Scandinavia there is too short a time between the beginning of cultivation of a field in the spring and the seeding of the field to utilize chemicals like the two mentioned ones for control of wild oats without being harmful to the crops. It has also been shown in a series of experiments that chemicals against wild oats are not reliable. As was pointed out by Petersen (24), Seischab (27), Bachtaler (6) and again at the International Congress of Crop Protection in Hamburg by Åberg and Wiberg (4) a crop rotation in which the crops are good competitors and in which there are possibilities for mechanical methods is a necessity for the control of wild oats and must be assisted simultaneously with good methods for preventing the spread of wild oat kernels. We also need to know how different varieties and forms of wild oats react. More studies of the biology of wild oats are needed. Chemicals are not enough.

Both TCA (trichloroacetic acid) and 2,2–dichloropropionic acid have an effect on quackgrass. But the way these chemicals must be applied and their after effect limit their use on cultivated fields.

Especially in areas with long and cold winters and dry springs the after effect can be disastrous. Therefore it is not surprising to find as a common recommendation mechanical methods against quackgrass in crops where such methods can be used.

Loose silky bent (*Apera spica venti* PB) is increasing in number, difficult to eradicate and appearing especially in areas where winter cereal acreage is continuously increasing. As indirect but effective measures against it in western Germany Diercks (10) mentions soil drainage, liming, fertilizing, well prepared seed beds etc. Among direct control measures he gives the use of calcium cyanamide in young stages of development. A good stage for the treatment is when the plants have four leaves. At that time 200 kg per hectare calcium cyanamide should be used. These recommendations are in agreement with Strycker's findings in Belgium in 1951 (32).

The three examples of grass species appearing as severe weeds in different parts of Europe and of the methods for controlling them remind us of the difficulties encountered in killing weeds of the grass family and of the lack of chemical weed killers effective against such weeds. There is not enough known about the biology and physiology of weeds of this type to make it possible to search for chemicals able to control them.

This gives reason to return to the question I raised a while ago, namely: Will we be able to change the chemical composition of certain parts of the weeds or of the cultivated plants by spraying with growth regulating substances like the ones now used for weed control? There is a special reason for raising this question. At the Third British Weed Control Conference 1956 I mentioned (3) investigations by Aamisepp at the Institute of Plant Husbandry in Uppsala in which he had in 1955 found that seeds of weed species with dormancy could be stimulated to an increased germination through spraying the weeds with chlorinated phenoxyacetic acids. The studies went on also in 1956 and 1957 and will be continued further. In 1956 it was observed that of seeds of cleavers, corn spurrey (*Spergula arvensis* L.) and pale persicaria (*Polygonum lapathifolium* L.) that had fallen on the ground before harvest, those that came from plots treated with 2,4–D or 2,4,5–T germinated before the ploughing of the field on October 19, while the ones from the unsprayed plots had not germinated at that time. From Aamisepp's studies, which will be summarized in a preliminary report in 1958[4] the following can now be reported:

In his investigations Aamisepp used weeds that were susceptible, medium susceptible or resistant to spraying with chlorinated phenoxyacetic acids. In the susceptible group he had, among others, lambsquarters. It has a dormancy caused by a hard seed coat and requires an after ripening process in cool and moist environment. Aamisepp sprayed it in an early stage of development and in a late one, using 1, 2, 4 and 8 moles of 2,4–D or 2,4,5–T per hectare. Early spraying (in the seedling stage) with as low amounts as 1 and 2 moles

[4]In the Annals of the Royal Agricultural College of Sweden, Uppsala.

per hectare lowered the seed production while late spraying (at the end of the flowering) increased it. This was the case for both chemicals. The germination increased after both sprayings and after both chemicals and rose from about 30 per cent to between 60 and 70 per cent.

In the medium susceptible group Aamisepp used scentless mayweed. It is fall-germinating. Both early and late sprayings with 2, 4 and 8 moles per hectare of 2,4–D or 2,4,5–T were used. Early spraying had a favorable effect on the germination of the seed. With increasing amounts of 2,4–D or 2,4,5–T the germination also increased so that 8 moles per hectare gave a germination of the seeds that was almost twice as high as of the seeds from untreated plots. Late spraying on the other hand lowered the germination ability of the seeds.

Most interesting is the effect of chlorinated phenoxyacetic acid on the properties of seed from species resistant to treatment with these substances. Two examples will be chosen. In cleavers seed setting increased after early spraying (in seedling stage) but decreased after late spraying (in late flowering stage). Both 2,4–D and 2,4,5–T at 4, 10 and 20 moles per hectare were used. Germination of the seeds seemed to be favored by early treatments, especially when 2,4,5–T was used. Further investigations are, however, necessary in the studies of this resistant weed species. In wild oats early spraying (in seedling stage) increased the seed set while late spraying (immediately before heading) decreased it. Also in this experiment 4, 10 and 20 moles per hectare were applied. However, it was interesting to note that late spraying increased the germination of the normally dormant wild oat kernels from about 40 per cent to somewhere between 80 and 90 per cent. For the germination of wild oat seeds, falling on the ground after the harvest in the fall, this treatment may open a possibility to get the wild oat kernels to germinate immediately after they ripen. They could then be killed by stubble treatments. Normally the wild oat kernels need alternations in temperature and moisture in the soil for breaking the dormancy as Bachtaler (6) has pointed out.

What happens inside the seed is not yet known. Chromatographic studies, now under way, may give some information. Aamisepp has found morphological changes in the plants the year he sprays the plants. We all know that this is possible. But he has in his investigations in 1957 been able to show that there is a seed-borne effect of chlorinated phenoxyacetic acid. In cleavers, for example, he found in 1957 plants originating from seed of cleavers treated in 1956, that differed from normal plants. Two types of such deviating plants appeared. One had short internodes, short leaves and a bushy growth habit. It had only occasional flowers and hardly any seed setting. Another one had normal internodes, rather long and very well developed leaves. The number of leaves in the whorl varied greatly from one internode to the other. The plants were rather slender and almost without hairs. They proved to be almost sterile.

The seed-borne effect can also be carried over from one generation

of cultivated plants to the other. Both for red clover and alfalfa Aamisepp found in 1957 that plants originating from seeds, collected on plots which were sprayed in 1956, gave higher forage yields than plants that came from seed from untreated plots. He used in the spraying in 1956 1, 2 and 4 moles of 2,4–D or 2,4,5–T per hectare. The result were better after 2,4–D than after 2,4,5–T. The root weight decreased, however. He could also prove a seed-borne effect in two-rowed barley, which above all showed up as an increased tillering of the plants.

Aamisepp's results draw attention to the effect of chemical weed killers on the composition, *i.e.* the quality of harvested products of cultivated plants, as bread cereal, malting barley, and feeding grain. There are reports on these particular problems from different parts of the world but it is not possible to judge as yet what the actual effect is. Experiments at the Institute of Plant Husbandry in Uppsala indicate that the chlorinated phenoxyacetic acids may have an influence on the quality of the carbohydrates in cereals. The results are, however, not enough for definite conclusions. The same is true for protein content in cereals and oil content in seed flax. If there is a definite influence this is prehaps best studied in investigations on the enzymatic conditions of harvested products. Such studies are now being planned. They will be closely related to Aamisepp's investigations. Detailed studies on the effect of chemical weed killers on the enzyme systems of plants and on the germination biology of seeds are only one part of the biological and biochemical research work that lies ahead of us. We are getting closer and closer to the question of the correlation between biologic activity of the plants and chemical structure of the weed killers.

In order to know what chemicals can be most advantageously used against different weeds and when they should be used it is thus necessary to study the biology and ecology of a number of weed species, especially of the ones that are only slightly susceptible or resistant to chemical weed killers. Many weeds could be chosen as examples on this. One is wild garlic (*Allium vineale* L.) that is common in certain areas in western Europe and Scandinavia. It has been studied by Lazenby (21), Orth (22) and Håkansson (17). As I have had the possibility of following Håkansson's work very closely I will mention a few results from his experiments which were started in 1954. Seed setting is rather poor and therefore the propagation depends mainly on the formation of bulbs and bulbils. Bulbils are found among the flowers at the top of the scape. Often the bulbs, the main ones and the side ones, are formed in the axiles of the leaves. Generally the bulbs and bulbils germinate the year they are formed, side bulbs one year after they are formed or even later. The best effect on wild garlic plants by use of mechanical means is obtained early in the spring. It must then be remembered, however, that such treatments must be repeated year after year so that plants from the dormant side bulbs can be killed off, whenever they appear. Spraying with chlorinated phenoxyacetic acids (MCPA in cereals and 2,4–D in pastures) have proven useful. Just as mechanical methods they

must, however, be applied when the garlic plants are sensitive to a treatment, *i.e.* in early spring. What has been stated for wild garlic must be looked upon as an example of the need for future detailed studies of the biology and ecology of those weeds against which we need to get better weed killing methods than we have now. In Finland Paatela has taken up this question for perennial sowthistle *(Sonchus arvensis)*, in Denmark Petersen has studied such problems for wild oats (24), in Belgium Slaats and Stryckers (28) have pointed out the necessity of investigating closely the reaction of pasture weeds in different stages of development to different weed killers.

If chemicals are to remain with us as important weed killers more must be known about the breakdown of these chemicals in the soil. In this field there is room for many investigations. Audus' work in England (5), Stapp's and Freter's in Germany (30, 31) and Jensen's and Petersen's in Denmark (18) have inspired to further studies which have, however, not been numerous enough and therefore not given a good enough picture of the effect of chemical weed killers on the soil microorganisms. Köhler (20) touched on this problem in a study at Stuttgart-Hohenheim. On basis of his experiments and literature studies he concluded that 2,4–D, 2,4,5–T and MCPA can be harmful to certain soil organisms in the upper soil layer during a short period of time. This would make it possible for some parasitic organisms to increase in number. Köhler believes, however, that even if this would happen it would not be on such a scale that it would have an influence on the agricultural production.

In 1957 Beinhauer (7) summarized his investigations on the inactivation of the sodium salts of dichloropropionic acid and of trichloroacetic acid during the years 1953–1956. A detailed report will appear later.[5] He found that the disappearance of these chemicals was due to leaching and microbial decomposition. Leaching is dependent on type and amount of precipitation and microbiological breakdown on temperature and soil moisture. Cold conditions as well as dry ones will slow up or stop the decomposition. Both chemicals will have an inhibiting effect on the activity of the microorganisms in the soil. This inhibiting effect will, however, be reduced a few weeks after they are applied. Beinhauer's findings agree closely with Thieg's results in this country in 1955 (33).

As Woodford (35) pointed out in 1956 very little field or laboratory work has been carried out in Europe for studies of spraying technique and its importance for weed control. Varying amounts of liquid per hectare and varying droplet sizes do undoubtedly effect the result of spraying. The work by Frazer (11) in England should be mentioned in this connection as well as the studies by Hellqvist (16) and Bengtsson (8). At an earlier date (3) I have had the possibility of giving some details of Hellqvist's and Bengtsson's results. In 1957 Bengtsson summarized his results as follows:

> The effect of varying droplet sizes when spraying with two herbicides, MCPA (sodium) and dinitrobutylphenol (ammonium)

[5]In the Annals of the Royal Agricultural College of Sweden, Uppsala.

was studied. In the experiments an atomiser was employed leaving the following droplet sizes counted as volume (surface mean diameter $\frac{\Sigma nd^3}{\Sigma nd^2}$: 80,150 and 380 μ).

The results were:

A greater effect was obtained when MCPA was sprayed on plants as barley, peas and lambsquarters in small droplets than if it was sprayed in large ones. On the other hand the effect on more wettable plants as charlock was not influenced by droplet size.

In experiments with dinitrobutylphenol all investigated plants showed a stronger reaction for a small-droplet spray than for a large-droplet one.

The wettability of plants has great importance for an effect of the droplet size.

The statements by Bengtsson show the urgent need for more studies of the spraying technique in relation to biology and ecology of weeds and cultivated plants.

Problems, progress and organization of weed control in continental Europe is the topic I have treated. Sometimes it has been stated in the literature and in discussions that our weed control problems were solved once we got good chemical weed killers and used them efficiently. Such chemicals have, no doubt, meant good progress in weed control. They have, however, also given us a number of new, but interesting problems, theoretical as well as practical.

It is now very clear that there is a need for a continuous search for new chemicals in order to take care of those weeds which are resistant to already existing chemicals and therefore increase in number as their competitors among the weed flora decrease in number because they are susceptible to now existing weed killers. So far we can talk about differences between weed species; after a few years we may have to talk about differences in resistance between varieties and forms within the species.

But even if new chemicals appear and even if such chemicals are used in mixtures with old ones or in alternation with these they alone are not likely to solve our problems. There is still a need for efficient crop rotations which favor the use of mechanical means and give the crops possibilities to develop well and compete with the weeds. I have earlier stated that there is no better weed control method than a thick, even and healthy stand of a crop. Quackgrass, wild oats and cleavers can be remembered in this connection. Here is room for biological control methods; in this case good crop rotations and mechanical methods.

Much work lies ahead of us. How this should be organized is of course a very important question. But in Europe, with so many differently organized countries, there will also be a number of different forms of organization. Important in this connection is only that the organization in each country is such that solving of new problems also means a further progress in weed control.

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The Role of Industrial Research and Development in Weed Control in Europe[1]

E. Holmes[2]

I feel greatly honoured to have been invited to cross the Atlantic to address so distinguished a gathering in the weed research and control fields.

If I may start with a word of personal explanation, I have been associated with a major company in the British chemical industry for the past 30 years. For 27 of those years I have been engaged in experimental and development work in the crop protection field which today includes weed control as one of its main aspects. In those years I have been privileged to have been involved in the discovery and development of several major new products—notably BHC and its gamma isomer and, more important from the point of view of this morning's session, the plant growth regulator type of weedkiller—in particular MCPA and 2,4–D.

My work has taken me over most of Europe many times and, to that extent, I have first hand experience of its official and commercial research stations. I have been much further afield in the same way and am no stranger to this country; indeed I first came over here in 1935 and this is my eighth visit to your country in the past 5 years.

Introduction

In discussing weeds and weedkiller research and development with special reference to European industry I must say a word about our government, university and other official research workers and laboratories. It is fair, I think, to say that nearly all the major discoveries of weed killing chemicals have come from industrial laboratories, but those discoveries would seldom have been possible without the fundamental work previously carried out in the botanical, chemical and other disciplines by our more academic colleagues. Twenty five or thirty years ago, in Britain at least, there was considerable suspicion of industry in the minds of those academic workers—sometimes with good cause—but today I am glad to say that we work together, each in his own particular sphere, most amicably and fruitfully. The same can be said of Continental Europe.

There is another aspect of this relationship between academic and industrial work and workers. Last September I attended at Hamburg the Fourth International Congress of Crop Protection and had the good fortune to hear two excellent papers on weed research by Professor G. E. Blackman of Oxford, England, and Dr. A. S. Crafts of Davis, California. The main impression I brought away from that session was not of new discovery but that the recent work

[1]Invitational paper presented at the Weed Society of America Meeting, Memphis, Tennessee, January 14, 1958.

[2]Chmn, British Weed Control Council, Plant Protection Ltd., Fernhurst Research Station, Nr. Haslemere, Surrey, England.

of these men and their teams has now explained the scientific background to field observations made by us, and doubtless by them, 12 or 15 years ago. But these new items of knowledge will act as stepping stones to further advances in both the theoretical and practical aspects of our work.

Incidentally, and to contradict a statement I made just now, Professor R. L. Wain, leader of an official Agricultural Research Council team at Wye, England, did produce a new break in weed control when his fundamental studies led him to the butyric modifications of the original growth regulator weedkillers. I shall have more to say of that later.

EUROPEAN INDUSTRY'S CONTRIBUTIONS

European industrial research made its first significant contribution to modern weedkilling in 1934 with the discovery of the selective properties of dinitro *o* cresol (DNC) by the two French chemists, G. Truffaut and I Pastac (11), of George Truffaut & Co. of Versailles. They were originally investigating the fungicidal activity of organic dyestuffs and this work led them to a study of the effect of these dyes on plant tissues. Truffaut and Pastac found that the susceptibility of plants varied from species to species and with the age of the plant. They came to realise that by selecting a suitable dye and choosing an appropriate dosage rate results of practical value to agriculture could be achieved, notably the destruction of wild mustard and thistles in cereal crops, without significant damage to the cereals.

Agriculturists even at that time were well aware of the crop losses caused by weed competition in cereals, and this discovery in France was followed up by much development by W. E. Ripper and his co-workers of Pest Control Ltd., of Harston, England. They confirmed that the most effective of these organic dyes was DNC and they established the optimum rates, times and methods of application to control weeds in cereals. They also did a lot of interesting development work on dinitro *o* secondary butylphenol (dinoseb) but that was, of course, an American discovery.

The disadvantages, however, of DNC were also high-lighted, particularly its toxicity to man and its failure to control buttercups and poppies.

The growth regulators

By far the most outstanding advance in weed control methods was the discovery, in 1940–42 by my colleagues W. A. Sexton, R. E. Slade and W. G. Templeman of Imperial Chemical Industries Ltd. (9) at Jealott's Hill, England, that synthetic plant growth regulators were effective as selective weedkillers. This was a revolutionary discovery. Like DNC, these growth regulators were toxic to many broad-leaved plants but not to cereals. There are, however, many differences. The selective weedkilling properties of DNC and sulphuric acid depend mainly on differences in morphological form between

the dicotyledonous, broadleaved and the monocotyledonous plants. The selective toxicity of growth regulating chemicals does not depend only on differences in external plant form and, although the physiological action of these compounds is not yet fully understood, it is believed that there is a fundamental difference in biochemical reaction between mono- and dicotyledonous plants.

The discovery of the plant growth regulator weedkillers by our British team was, as so often happens, the result of a piece of acute observation. Templeman was initially testing the effect of the naturally occurring growth regulator α-naphthylacetic acid on crop yield. Boxes of soil containing mixed seed of oats and wild mustard were sprayed at rates equivalent to 10 to 25 lb. per acre; it was found that the germinating wild mustard seedlings were suppressed without harmful effects on the oats. This was followed by observations of similar effects on the growing plants. These heavy rates of application, however, meant that this work, although scientifically interesting, was not of direct practical farm value. Sexton of our Dyestuffs Division Laboratories was then called in to produce synthetic chemicals which might have effects similar to, but more interesting on a cost/efficiency basis than those of the naturally occurring plant growth regulator. The outcome of this collaboration between biologist and chemist was the selection of two chemicals, 2–methyl–4–chlorophenoxyacetic acid (MCPA), and the corresponding dichloro-compound, 2,4–D, as the most promising compounds for agricultural development.

Field work by us and by official research organisations both in Britain, notably Blackman's Agricultural Research Council team at Oxford (1), and the United States during 1943 onwards showed that these chemicals at rates of 1 or 2 lb. per acre, sometimes less, suppressed many of the prevalent annual weeds and some perennial weeds growing in cereal crops. Today, as we all know, MCPA in Britain and 2,4–D in the United States are in huge practical use for cereal growing, indeed they are used in all parts of the civilised world.

Although Sexton, Slade and Templeman first discovered that both MCPA and 2,4–D were extremely active selective weedkillers, it is only fair to add that in this instance industry was but little ahead of workers at the official research stations of Rothamsted in Britain (8), the Boyce Thompson Institute here at Yonkers (4) and the U.S.D.A. at Beltsville (7).

Another piece of research carried out at the Jealott's Hill station led to the discovery of the weedkilling properties of IPC, iso-propyl-phenylcarbamate or propham (10). During the studies on plant growth control by chemical compounds it was noticed that some compounds affected cell extension while others interfered with cell division. IPC amongst other compounds was found to arrest cell division of cereal seedlings at low concentrations—in the region of 10 ppm. In heavier applications IPC prevented the further growth of established cereal plants when these were in flower. At the same time the chemical had no effect on cell division and growth of man-

golds, sugar beet, flax and wild mustard. It would appear that the action of IPC and other carbamate esters on monocotyledonous plants and lack of action on dicotyledonous was roughly the converse of the action of the phenoxyacetic acid class of plant growth substances. IPC has since proved to be a very useful addition to the weedkiller range for the control at 4 to 8 lb. per acre of, for example, annual grasses in seed beds and wild oats *(Avena fatua)* in peas. You in America, of course, added the chlorine to give CIPC.

The butyrics and propionics

The discovery by Wain and his colleagues at the Agricultural College of Wye, England (12), in 1954, of the phenoxy-butyric acids as selective herbicides was followed by much development work by many commercial firms, but particularly by K. Carpenter, M. Soundy and C. Wilson of May and Baker Ltd. of Dagenham, England (2, 3). The phenoxy-butyric acids, MCPB and 2,4–DB, have filled yet another gap in the weedkilling range. Since it is postulated that the phenoxy-butyric acids must first be converted by beta oxidation in the plant to phenoxyacetic acids before having any phytotoxic effect, and since plants vary in their enzymatic ability to carry out this conversion, MCPB and 2,4–DB do not have such a wide weedkilling range as their corresponding acetic derivatives, but are consequently safer to use on a wider range of crops. Leguminous crops in particular are unable to carry out this conversion to any appreciable extent and both MCPB and 2,4–DB are therefore safe to use and are particularly valuable for weedkilling in these crops. Undersown cereals, clover leys, clover for seed, alfalfa and certain varieties of peas are now widely treated with these phenoxy-butyric derivatives.

I am aware that the beta oxidation theory does not account for all the facts.

This tendency for herbicides to be developed for increasingly specific purposes has been further illustrated by the work of G. B. Lush and E. L. Leafe of the Boots Pure Drug Co. of Nottingham, England, during 1956 (6). These workers were looking specifically for a chemical which would control cleavers *(Galium aparine)*, a major cereal weed problem in England, particularly in winter wheat. The increased use in the last 10 years of MCPA and 2,4–D, to which cleavers is resistant, together with combine harvesting methods has intensified this problem in spring as well as autumn sown cereals and, apart from competition for soil moisture and nutrients, dense stands of cleavers pull down cereal crops—causing harvesting difficulties and loss in yield. In the past DNC has been the only method of control.

Lush and Leafe examined by means of glasshouse screening tests a large number of compounds of the phenoxy-alkyl type. Results showed that two compounds, α(2,4–dichloro–3–methyl phenoxy) propionic acid and α (4–chloro–2–methyl phenoxy) propionic acid, killed cleaver plants at 2 lb. acid equivalent per acre. The first compound was substantially specific for cleavers alone but the second was found to have a much wider weed control range. It has now been

given the abbreviated name CMPP. Further field trials and development work this year have shown that CMPP has a weed control spectrum roughly the same as MCPA with the addition that it controls cleavers. CMPP, however, must be applied at approximately twice the rate of MCPA or 2,4–D. On synthesis the α phenoxy propionic acids occur as mixtures of equal parts of the dextro rotatory and the laevo rotatory optical isomers. Only the former is active; but separation is not economically feasible so that the CMPP formulations now coming into general use for cleavers control in Britain have to be applied at the higher rates.

The triazines

Finally, in 1956, H. Gysin and E. Knüsli, working for the Geigy Co. of Basle, Switzerland (5) discovered the herbicidal properties of the *s*-triazine derivatives. These constitute a completely new group of synthetic chemicals found to have plant growth regulating properties. According to these authors the chemicals were discovered not by the empirical testing of vast numbers of assorted chemicals but, for the first time, by theoretical reasoning. Gysin and Knüsli were interested in the urethane type of chemical. Field tests with Du Pont's monuron (CMU) indicated that both the aryl urethanes and the aryl ureas had interesting herbicidal properties without the selectivity between mono- and dicotyledons shown by 2,4–D or MCPA and IPC. They were struck by certain similarities in structural formulae of 2,4–D, IPC, monuron and triazine. They therefore substituted the carbonyl group of an urea by a triazine-ring and tested various chlorinated derivatives for herbicidal activity. Several were found to show promise and simazin, 2–chloro–4,6–bis (ethylamino)–*s*–triazine, is already available on the market both for total weed control and pre-emergence weed control in corn.

CONCLUSIONS

Looking back through my notes for this paper I find I have said much more about British weedkiller work than about that of Continental Europe. Frankly I do not believe that this is due to any bias because I happen to be British; it is simply a fact that until recently more work and, as it happens, more rewarding work has been done in Britain.

I have been asked how many fulltime workers we have on weedkiller research and development in Europe, including Britain. I estimate that in Britain we have about fifty graduates in industry and rather fewer in the official stations; with non-graduate assistants, probably rather fewer than two hundred and fifty in all. I have no similar figures for Continental Europe outside the Iron Curtain, but it must be of the order of two or three times those I have just given.

Apart from the Swiss work by Geigy to which reference has been made, I know that a great deal of interesting work on weedkillers is going on, for example, by Farbenfabriken Bayer of Leverkusen and the Badische Anilin und Soda Fabrik of Ludwigshafen in Ger-

many. More is going on in Sweden, but this is mostly university work as my good friend Dr. E. Åberg knows better than I.

As and when all this new work is published we shall find that we have increased our knowledge of what goes on inside plants, including weeds, and of the fate of chemical weedkillers in those plants. The farmer will have been provided with even newer techniques and chemicals to solve his weed problems—to the benefit of crop production, and of mankind.

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The Impact of Public Law 518 on Herbicide Research and Recommendations[1]

H. L. HALLER[2]

NOT more than 5 years ago the subject of herbicide residues on food probably would not have aroused too much interest. Such is not the case today. Aware as you are of the improvement in agriculture practice that can stem from herbicide usage, you doubtless are also familiar with the associated residue problem. My purpose this morning is to comment on some aspects of that problem from the standpoint of recent legislation.

Although residues of herbicides as possible health hazards on fruits, vegetables, and forage crops have been of more recent concern, pesticide residues especially those of insecticides, have been given attention for many years by workers in the pest control field.

As early as 1897 the Annual Report of the Massachusetts Board of Health called attention to residues of lead arsenate which had only a few years before been introduced for gypsy moth control. Since that time many reports of pesticide residues on a wide variety of crops and soils have been published. In the early 1920's an event occurred that had an important bearing on the residue problem. Several thousand people in England were poisoned by drinking beer! Investigation developed that the beer contained arsenic and led to regulations limiting the amount of arsenic permitted in foodstuffs. A tolerance of 0.01 grain (1.43 ppm) of arsenic calculated as As_2O_3 per pound of food was set. But this limit was apparently not rigidly enforced because a few years later following the reported illness of several persons after eating American apples, the English authorities began rejecting shipments of apples found to be above the legal tolerance. The problem was of concern to American apple growers and at their request Congress appropriated money specifically for residue studies. A number of the states and industry also undertook studies on the subject. Inorganic chemicals were the principal pesticides those days and residues of lead arsenic, fluorine, and mercury were of greatest concern.

The first formal step in administratively controlling spray residues on food for the protection of the consumer was taken in 1938 with the enactment of the Federal Food, Drug, and Cosmetic Act. The Act, among other things, prohibited the shipment in interstate commerce of adulterated food. It provided that a food was adulterated if it contained any added substance which was not required in the production of food or which could be avoided by good manufacturing practice. It further provided that when such a substance was so required or could not be avoided the administrative agency should set up regulations limiting the quantity which could legally remain on the food. Since most pesticides used in food production are

[1]Invitational paper presented at the Weed Society of America meeting, Memphis, Tennessee, January 13, 1958.

[2]Asst. to Administrator, Production Research, ARS, USDA, Washington 25, D.C.

recognized to be either "poisonous or deleterious" and since they are "required" in the production of food, it was anticipated in 1938 that pesticide residues would be controlled under such regulations. The Act functioned reasonably well for more than 10 years. But with the advent of many new pesticides some individuals and agencies became alarmed that poisonous residues might remain on food crops. Following a congressional investigation a number of bills, some proposing quite drastic legislation, were introduced in both the House and Senate to control or regulate pesticide residues on foods. The Miller Bill which was deemed as being most equitable to all, finally was passed on July 22, 1954, as the Miller Pesticide Residue Amendment to the Federal Food, Drug, and Cosmetic Act. It is formally known as Public Law 518 of the 83d Congress.

I cite this brief history because of the feeling among some people that research workers in agriculture do not give enough attention to pesticide residues and that our food supplies are being exposed excessively to pesticides. There is ample evidence that research workers make every effort to find the minimum amount of a pesticide that is necessary to control a pest. This effort is made in the interest of both health and economy. Although the evidence indicates that if properly used, pesticides are not a health hazard, research workers in pest control must continue to be on the alert to insure maximum safety.

The specific objective of Public Law 518 is to protect the consumer from injury through consumption of excessive and harmful residues of pesticide chemicals on food in its raw or natural state, including all fruits, vegetables, nuts, eggs, raw milk, forage, and meats. The new Law recognizes that sprays and dusts are necessary to assure a continuing supply of high quality foods, and it is designed to permit their use without hazard to the consumer. It permits a flexible type of procedure and, basically, replaces the old procedure, which required a formal public hearing before a tolerance could be established.

To obtain a tolerance, under Public Law 518, the manufacturer or interested person submits the following information to the Food and Drug Administration and the U. S. Department of Agriculture:

(1) Data showing the effectiveness of the chemical to control the pest for which it is intended and the commodity to be treated.
(2) Amount of the residue which will remain in or on the crop when the chemical is used in accordance with label directions, including a description of the analytical method used.
(3) Full report as to the safety of the pesticide chemical.
(4) Practicable methods for removing the residue which exceeds any proposed tolerance.

The Department of Agriculture's responsibility under the new Law is in connection with the registration under the Federal Insecticide, Fungicide, and Rodenticide Act of only those pesticides that may leave residues on or in raw agricultural commodities. The Department is required to send a certification to the Food and Drug Administration as to whether the product under consideration is

useful for the purpose intended. An opinion is also required as to whether the tolerance or exemption proposed reasonably reflects the amount of residue likely to result when the product is used as intended. Following certification by the Department of Agriculture, the Food and Drug Administration determines what residue of the pesticide will be without hazard to man and establishes the tolerance. The tolerance for any pesticide is not always set at the highest level consistent with safe consumption of a treated crop but is set at the lowest possible level consistent with safety and the effective use of the pesticide concerned. Thus, it is possible for a relatively safe pesticide to have a lower tolerance than a more toxic one. This is in accord with the fundamental philosophy that food shall not carry any more than is absolutely necessary of a substance that is not normally present. There has been some tendency to relate the tolerance established to acute or chronic toxicity of a pesticide. For example, one chemical may be reputed to be ten times as toxic to warm blooded animals as another. If a tolerance of 10 ppm is established for the less toxic chemical, it does not follow that the more toxic chemical will be granted a tolerance of 1 ppm.

When registration under the Federal Insecticide, Fungicide, and Rodenticide Act is requested for the use of a pesticide for which no residue has been found, all data, including analyses of untreated products and the sensitivity of the analytical method used, will be considered. In some cases the data will be discussed informally with representatives of the Food and Drug Adminstration to determine whether they can be accepted as adequate proof of absence of residue. If it is determined that no residue will occur in the treated products it will not be necessaary to obtain a tolerance or exemption from tolerance.

Under Public Law 518, all pesticides fall into one of four classes: (a) *Safe Chemicals.* These may be used without a tolerance or exemption. Lime, sulfur, and various combinations of the two are in this category. None of the herbicides are so classified.

(b) *Chemicals exempt from the requirement of a tolerance.* Such chemicals have been exempted because they are low in toxicity and their use in accordance with good agricultural practice on growing crops will not result in harmful residues. Certain copper compounds, petroleum oils used as dormant sprays or herbicides, and several plant insecticides and synergists fall into this class. These pesticides are not automatically exempted from the requirement of a tolerance when applied to a crop at the time of or after harvest. As mentioned above, only petroleum oil herbicides are exempt from a tolerance.

(c) *Chemicals with a zero tolerance or the equivalent.* These are chemicals which are so toxic that no residue should remain on food as it is marketed or they are chemicals that have not been studied enough to show whether a higher tolerance is warranted. Certain mercury compounds and substituted dinitrophenols which are used as herbicides are examples of chemicals having a zero tolerance because they are too toxic.

Official tolerance for these herbicides has not been established

under Public Law 518. However, following the 1950 hearing on pesticide residues in food the Food and Drug Administration directed that they should be used only under conditions that leave no residue on fruits and vegetables as prepared for market.

There has been considerable discussion of what is meant by "the practical equivalent of zero". This question arises in connection with the presence on foodstuffs of a chemical in such small quantities as to represent a toxicologically trivial amount. As an example, a certain operation may introduce mercury into an edible oil at a level of three parts per billion yet the tolerance for mercury in foodstuffs is zero. Two separate *ad hoc* Sub-committees of the Food Protection Committee, National Academy of Sciences considered the problem. One of the committees concluded that there is no scientific basis for designating a finite quantity as zero but added that "it might be expedient legally to do so". The other sub-committee unanimously agreed that a basis does exist for considering trivial quantities of chemicals in food as insignificant or inconsequential and that there is both scientific and practical justification for this. It is clear from these two reports that the problem is an exceedingly difficult one.

(d) *Chemicals for which tolerances have been granted.* Tolerances or exemptions have been granted for approximately 90 pesticide chemicals involving a total of more than 1,600 individual uses. These include nine herbicides involving about twenty different crops. Some are based on the 1950 spray residue hearing and some result from the new procedure.

It should be noted that a tolerance is established for the use of a chemical on a specific crop and does not apply to all other crops. For example, a tolerance of 2 ppm has been established for sesone on asparagus and strawberries but when used on peanuts and potatoes the tolerance is 6 ppm. In the case of these crops separate residue data had to be submitted for each crop. To reduce the amount of research the Food and Drug Administration has made a tentative grouping of some crops. For example, when data have been submitted to justify establishing a tolerance for a given chemical on alfalfa, less complete information will be needed to extend that tolerance to clovers, cowpea hay, lespedeza, lupines, peanut hay, pea-vine hay, soybean hay and vetch. Up to the present, however, data on one member of a category have not permitted the establishment of tolerances on all crops in the list.

Last May the Pesticide Regulation Section of the U. S. Department of Agriculture issued a "Summary of Certain Pesticide Chemical Uses". The summary lists the tolerances and exemptions of those pesticide chemicals registered under the Federal Insecticide Act and which come under the jurisdiction of Public Law 518 and which will meet the requirements of that Law when the application pattern and limitation shown for each chemical is followed. Registrants are expected to use the summary and if the claims made on the label of their product are not covered by a tolerance or exemption they will be expected to obtain the necessary data or submit revised labels for registration. Recommendations for the use of herbicides in fruits,

vegetables and forage should not be made where it is known that a residue occurs and no tolerance or exemption has been established. Recommendation should also be withheld if it is known that the residue will exceed the tolerance established for the herbicide and commodity involved unless a modified recommendation can be made to avoid exceeding the tolerance. The list is being kept current by amendment sheets which are distributed periodically.

Plant growth regulators, defoliants, desiccants and sprouts inhibitors are not regulated under the Federal Insecticide, Fungicide and Rodenticide Act and therefore Public Law 518 does not apply to them. However, if their use leaves a residue on food they are subject to the Federal Food, Drug, and Cosmetic Act and therefore a tolerance or exemption must be obtained under Section 406a as amended by Public Law 905. To obtain a tolerance under the amended Section 406a it is required that *necessity for the use* be established to the satisfaction of the Food and Drug Administration. Public Law 518 on the other hand requires only that a pesticide chemical is *useful* for a specific purpose.

Now, what are some of the problems that still confront herbicide workers? One of the most important is the need of residue data for those chemicals which were approved for use on certain crops prior to the enactment of Public Law 518 but for which no tolerances or exemptions have as yet been established. For example, residue data are lacking for 2,4–D where it is used on grass pasture and rangeland intended to be grazed by milk and meat producing animals. The status of MCPA is similar to that of 2,4–D. The only acceptable food use for 2,4,5–T is on rice. Other uses of this chemical on food crops are in need of residue data. Residue data are also needed on the related propionic and butyric phenoxy compounds. The list is, of course, not complete.

The question has been raised as to whether residue data on one herbicidal ester would be sufficient to cover other esters of the same acid. The interpretation by the law enforcement officials has been that each chemical must be evaluated on the basis of its pharmacology and residue data. If two or more esters exhibit similar pharmacological behavior it is likely that less residue data would be required for other esters of the same acid provided that the residue data were of the same magnitude in both cases.

In some instances, registration has been granted on the basis of meager data that indicate no residue would be present on the harvested crop. Additional data may be needed to assure continued label approval. These problems apply particularly to the use of pesticides on minor crops or to limited uses where industry has been reluctant to finance the cost of collecting the required residue data because of the limited sales potential. Research workers realize there may be a Government interest in such cases, particularly where the uses are included in Federal or State schedules. Possibly such problems can be solved by Government-industry cooperation. As a step in this direction in April, 1956, our Field Crops Research Branch issued "Suggested Guide for Chemical Control of Weeds", ARS

22–23. This guide summarized the recommendations of the four regional conferences on weed control. The information in this handbook was compiled in consultation with the Pesticide Regulation Section and the Federal Extension Service. The recommendations are not being revised.

And now in closing, although outstanding progress has been made in research with herbicides during the last few years much remains to be learned for their most effective use. When used on food plants a knowledge of the factors influencing their absorption, translocation, and distribution and breakdown is important. Research findings indicate that most of the modern organic weed killers break down reasonably quickly. However, to comply fully with Public Law 518 information must be obtained on the metabolites as well as their toxicity and the extent to which they may be present when used on food plants. Full compliance with Public Law 518 requires the cooperative effort of research workers and those responsible for the enforcement of the Law.

Absorption and Translocation of Radioactive 2,4–D in Sugarcane and Bean Plants

FLOYD M. ASHTON[1]

THE plant growth regulating properties of 2,4–D (2,4–dichlorophenoxyacetic acid) (26) and the resistance of most monocotyledonous plants to the toxic effect of this chemical (17) have been known for many years. This difference in sensitivity of various species to the toxic effects of 2,4–D has had wide practical use in the field of weed control. However, there is no generally accepted mechanism for the selectivity between sensitive and resistant plants or for the actual mechanism of 2,4–D action. The four areas of research which have been investigated to elucidate the mechanism of action are absorption, translocation, and two distinct metabolic approaches. Absorption and translocation are often studied simultaneously. Metabolism is studied from two approaches, either the fate of 2,4–D in the plant or the effect of 2,4–D on plant metabolism. All of these processes are operating simultaneously in the plant and the ultimate explanation as to the mechanism of 2,4–D action must incorporate all of the contributions from these areas of research.

The study of the physiology of the action of herbicides has been markedly handicapped by the lack of methods for the quantitative determination of these chemicals. The lack of methods is due in part to the extremely low concentration of these chemicals found in plant tissue. Hay and Thimann (11) have recently presented a critical discussion of the methods used by workers investigating the mechanism of 2,4–D action.

Many workers (7, 18, 20, 21, 22, 23) have used various biological assays for studying the absorption and translocation of 2,4–D. All of these methods lack the specificity desired and most of them lack sensitivity. The method of Hay and Thimann (11), using the split pea test after certain isolation procedures, has the required specificity but lacks sensitivity.

Other workers (1, 2, 3, 4, 5, 6, 8, 9, 10, 12, 13, 14, 15, 16, 19) have used radioactive tracer techniques for studying the translocation of herbicides. Most of these workers have not isolated the herbicide prior to counting; therefore, it is not known whether the activity is due to the applied herbicide or to metabolic products. Workers using radioactive isotopes should not refer to the translocated material as the applied compound unless it is isolated and identified. Radioactive 2,4–D has been isolated and identified from plant tissue by counter-current distribution (12, 13) and chromatographic methods (9, 14, 15, 24, 25) in metabolic studies. Radioactive 2,4–D has been isolated and identified from plant tissue by chromatographic techniques in absorption and translocation studies (9, 14).

The objectives of this investigation were to develop a simple method of high sensitivity and specificity for the determination of tagged

[1]Dept. of Botany, University of California, Davis.

2,4–D isolated from plant tissue and to use the method to study the absorption and translocation of 2,4–D in sugarcane and bean plants.

METHODS AND RESULTS

Bean *(Phaseolus vulgarus)* and sugarcane *(Saccharum officinarum)* plants were germinated in soil and were transferred to a complete inorganic culture solution just prior to the application of 2,4–D. Uniform plants were selected and the sugarcane and bean plants were of approximately the same total fresh weight. The bean plants had well developed primary leaves and the trifoliate leaves had just started to unfold when treatments were made. The sugarcane plants had two well developed true leaves and a third leaf rapidly expanding when treatments were made. Thirty-five micrograms of carboxyl-labeled 2,4–D (specific activity: 1 mc/m mole) in 0.1 ml of water was spread over the entire upper surface of one primary leaf of a bean plant and on the entire upper surface of the second fully expanded leaf of a sugarcane plant. The 2,4–D solution contained 1% Dreft as a wetting agent. The total surface area of the treated leaf was approximately equal in the two species. The bean plants were severely twisted in less than 18 hours. The sugarcane plants grew with no apparent ill effects. The plants were harvested after 7 days.

The plants were divided into several parts, weighed, and immediately placed in 40 ml of boiling 80% ethyl alcohol. The leaves that were treated with 2,4–D were washed three times with 80% ethyl alcohol before being placed in the boiling alcohol. These 80% alcohol washes were combined and the amount of 2,4–D present determined by the method described; the amount of 2,4–D present in this fraction was considered to be unabsorbed, the percent of 2,4–D absorbed was determined by difference. Each plant part was blended for 2 minutes in a micro Waring blendor, filtered through No. 1 Whatman filter paper and given two 25 ml washings with 80% ethyl alcohol. The alcoholic extract and washings were combined and heated on a steam bath until all of the alcohol had evaporated. The aqueous portion (about 3 ml) was placed in a 30 ml separatory funnel; the flask was washed with two small portions of water (about 3 ml); and the washings were added to the separatory funnel, which made the final volume about 10 ml. One drop of concentrated hydrochloric acid was added to the separatory funnel and shaken; the pH was 1.8. Ten ml of anhydrous diethyl ether was added to the separatory funnel. The mixture was shaken for 2 minutes. The 2,4–D quantitatively moved into the ether layer. When the two layers separated, the aqueous phase was removed and discarded. Ten ml of a 1% sodium bicarbonate solution was placed in the separatory funnel and shaken for 2 minutes. The 2,4–D quantitatively moved into the bicarbonate phase. When the two layers separated the sodium bicarbonate phase was placed in a 15 ml centrifuge tube, four drops of concentrated hydrochloric acid were added, mixed, and allowed to remain over night; the pH was 1.8. The overnight period is necessary to allow the carbon dioxide to escape prior to the addition of Norite, an activated carbon, and stoppered shaking. Without

this delay the developed pressure would dislodge the stopper. Ten mg of Norite were added, the centrifuge tube was stoppered and shaken 10 minutes on a mechanical shaker at 60 cycles per minute. The tube was placed on its side during the shaking operation. During this process the 2,4–D was quantitatively adsorbed on the Norite. The Norite was centrifuged down and the supernatant solution decanted off. The Norite containing 2,4–D was suspended in 2 ml of water and placed in a cupped planchet having a surface area of 10 cm^2. The Norite was allowed to settle to the bottom of the planchet and dried without moving with an infra-red heat lamp. Moving the planchet prior to drying disturbs the evenly distributed Norite and could give inconsistent counts. The planchet was counted with a windowless flow counter. The recovery of 2,4–D, in the absence of plant tissue, using this isolation procedure is shown in Table 1.

Table 1. Micrograms of 2,4-D in residues after extraction in isolation procedure, using 12.5 micrograms of 2,4-D.

Fraction	Micrograms of 2,4-D
Aqueous residue	0.01
Ether residue	0.06
Sodium bicarbonate residue	0.00
Norite	12.43
Percent recovery	99.4%

The use of activated carbon to adsorb the radioactive 2,4–D in preparing samples in very thin layers is an excellent method of obtaining relatively high counts on micro amounts of material. This technique gives a very uniform distribution of radioactive material on the planchet and the amount of Norite required does not appreciably lower the count due to self absorption. One hundredth of a microgram of 2,4–D gives 5 counts per minute in the windowless flow counter used. The relationship is linear in the range covered in this experiment. When a constant amount of 2,4–D is adsorbed on varying amounts of Norite, the lower amount of Norite fails to adsorb all of the 2,4–D and the higher amounts tend to lower the counts due to self absorption (see Table 2). The routine isolation

Table 2. Adsorption of one microgram of 2,4-D by varying amounts of Norite.

Mg. of Norite	Norite counts/min.	Residue counts/min.
1.0	420	100
3.0	495	5
5.0	485	0
10.0	485	0
25.0	430	0

procedure used 10 mg of Norite in a planchet having a surface area of 10 cm^2.

It has been demonstrated that 2,4–D is the only radioactive substance isolated from bean plants using this method. This has been

shown by the appearance of only one spot on a radioautograph of a two-dimensional chromatogram when pure radioactive 2,4–D and the plant isolate were co-chromatogramed. The solvent systems were butanol: propionic acid: water (12:5.6:8) (15) and butanol:1.5N NH_4OH (1:1).

The distribution of the absorbed and translocated 2,4–D in the sugarcane and bean plants is shown in Table 3.

Table 3. Total amount and concentration of 2,4-D in various parts of sugarcane and bean plants.

Sugarcane			Bean		
Plant part	Total 2,4-D-micrograms	Concentration micrograms of 2,4-D/gm. fresh weight	Plant part	Total 2,4-D-micrograms	Concentration micrograms of 2,4-D/gm. fresh weight
Spindle	0.22	0.22	—	—	—
Growing point	0.02	0.22	Growing point	0.44	2.32
Stem	0.18	0.33	Internode, 2nd	0.24	0.48
			Internode, 1st	1.95	1.39
			Hypocotyl	1.51	0.70
Blade, 4th	0.15	0.08	Trifoliate	0.22	0.35
Sheath, 4th	0.03	0.30	Petiole	0.19	0.70
Blade, 3rd (treated)	9.01	5.96	Primary (treated)	1.29	1.08
Sheath, 3rd	1.02	0.58	Petiole	0.11	0.31
Blade, 2nd	0.01	0.01	Primary	0.01	0.01
Sheath, 2nd	0.03	0.02	Petiole	0.01	0.03
Sheath and blade, 1st	0.03	0.04	—	—	—
Roots	0.02	0.01	Roots	0.13	0.03
Unabsorbed	1.82		Unabsorbed	5.94	
Recovered	12.54		Recovered	12.04	
Percent recovery as 2,4-D	35.8%		Percent recovery as 2,4-D	34.4%	

DISCUSSION

The sugarcane plants, a monocotyledon, and the bean plant, a dicotyledon, both readily absorbed the 2,4–D that was placed on their leaves. The sugarcane plant absorbed 94.8% of the applied 2,4–D and the bean plant 83.0%. Fang and Butts (9) have reported that 2,4–D is absorbed by monocots but at a slower rate in comparison with bean plants. The experimental data presented here do not agree with this generalization.

The sugarcane plant, which is more resistant to the toxic effects of 2,4–D than the bean plant, translocated this hormone-like chemical less readily than the bean plant. This is in agreement with the findings of Fang and Butts (9). The treated leaf of the sugarcane plant contained 93.5% of the total 2,4–D in the plant at the time of harvest. The treated leaf of the bean plant contained 23.0% of the total 2,4–D in the plant at the time of harvest. The concentration of 2,4–D in the various parts of the bean plant was higher than comparable parts of the sugarcane plant. The difference in concentration of 2,4–D in the vital growing point area of these two species was striking; the bean plant tissue contained ten times the concentration of the sugarcane tissue.

About one-third of the applied 2,4–D was recovered in both species. This finding is in agreement with the findings of Holley,

Boyle, and Hand (12). The two-thirds of the applied 2,4–D which was not recovered must have been converted into other substances, bound tenaciously to some plant material, or lost to the culture solution. Undoubtedly some 2,4–D was decarboxylated and released as $C^{14}O_2$. If the plant was in the dark when the decarboxylation occurred, some of the $C^{14}O_2$ probably would be lost to the atmosphere and some taken up by dark fixation, but if the plant was in the light when the decarboxylation occurred, most of the $C^{14}O_2$ would undoubtedly enter the photosynthetic mechanism to yield a number of labeled compounds.

SUMMARY

A method of high sensitivity and specificity for the determination of radioactive 2,4–D isolated from plant tissue is given.

The sugarcane and bean plants both readily absorb 2,4–D applied to their leaves. The resistance of monocots to the toxic effects of 2,4–D cannot be explained by the slower rate of absorption in all species. The bean plant transports 2,4–D more readily than the sugarcane plants, and has a higher concentration of 2,4–D in its tissues than the sugarcane plant at the time of analysis, particularly in the growing point. The resistance of monocots to the toxic effects of 2,4–D can be explained by the slower rate of translocation and the lower concentration of 2,4–D in its tissues. It is not proposed that these are the only factors determining this selectivity.

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Control of Wild Oats by Prevention of Normal Seed Development with Sodium 2,2–Dichloropropionate

ROBERT N. ANDERSEN and E. A. HELGESON[1]

IN 1954 the authors reported studies involving the application of sodium 2,2–dichloropropionate (sodium salt of dalapon)[2] to wild oats *(Avena fatua)* and concluded that treatment in the boot stage showed no promise in controlling viable seed production in wild oats. However, a lag in germination in seed from treated plants was noted in some instances (1). When seeds from these plants were planted in the greenhouse, many seedlings reached the coleoptile stage only, and failed to develop further (2).

The results of further work to determine the effect on wild oat seeds from parent plants treated with dalapon and the effects of such treatments on three crops are presented in this paper. The present work with dalapon is in some ways similar to that conducted with maleic hydrazide (MH), and a brief review of the use of MH for devitalizing wild oats seed seems appropriate at this time. The first work of this type was conducted by Knowles in 1952 and reported in 1953 (6). Knowles found that it was possible to cause sterility of wild oats seed without materially affecting the yields of barley and wheat. His work in 1953 indicated that MH applied to wild oats in the late flower to early milk stage, to flax in the boll, and to barley in the dough stage resulted in nearly complete sterility of the wild oats seed with little or no effect on the flax or barley.[3] Carder's work done in 1953 and reported in 1954 confirmed the possibility of selective sterilization of wild oats (3). Numerous workers tried the method in 1954 and 1955 using various rates and formulations of MH at different stages of wild oat growth. There was general agreement that MH did effectively devitalize wild oat seeds when applied in the milk stage. There was some disagreement as to the effect on seed viability of the crops involved and on the minimum effective rate. Rates of ½ to 1 lb/A seemed adequate. Friesen and Walker (5) reported no definite reduction in the wild oat population in 1956 on a 2 acre plot which had received a ½ lb/A treatment in the milk stage of the wild oats in both 1954 and 1955. Research on this method of wild oat control has been terminated by most workers largely for the reasons stated by Carder (4). These reasons are given in the discussion section of this paper.

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[1]Agronomist, Crops Research Division, ARS, USDA, formerly at North Dakota Agr. Exp. Sta., Fargo, North Dakota, now Dept. of Agronomy and Plant Genetics, Univ. of Minn., St. Paul, Minn. and Botanist, North Dakota Agr. Exp. Sta., Fargo, North Dakota, respectively.

[2]The authors wish to acknowledge the cooperation of the Dow Chemical Company for supplying the experimental samples of dalapon and for their support of some of these studies through grant-in-aid assistance to the North Dakota Agricultural Experiment Station.

[3]Knowles, G. The selective control of wild oats in barley and flax by maleic hydrazide. Unnumbered leaflet. Central Exp. Farm, Ottawa, Ontario. Dec. 21, 1953.

METHODS AND MATERIALS

Wild oat plants on a Fargo clay soil at Fargo, North Dakota, which had been infested with wild oats for 3 years, were allowed to go to seed before plowing in the late summer of 1955. An adjacent area which was free of wild oats was fallowed during the summer of 1955. This area was sown to one block each of Marine flax, Selkirk spring wheat, and Ramsey durum wheat in the spring of 1956. On May 18, 1956 both the wild oat area and the area to be sown to crops were disked and harrowed. The crops were sown the same day. It was hoped that the wild oats and crops would develop at the same relative rates. However, some wild oats which had emerged by May 18 were not killed by the disking and harrowing and the wild oat area therefore was disked and harrowed again on May 21. This delayed the emergence of the wild oats so that they were 3 days out of phase with the crops.

A split plot experimental design was used in these investigations. Stages of growth when treatments were applied were main plots and treatments were sub-plots. Individual plots in the wild oats were 5 by 14 feet. Three replications were used in the wild oats. Individual plots in each of the crops were one drill width (6 feet) by 14 feet. Drill rows in all cases were 7 inches apart. Four replications were used in the crops.

The wild oats and the crops were treated with 0, ½, 2, or 6 lb/A acid equivalent of dalapon[4] in 20 gal/A aqueous solution. In addition to the dalapon treatments, the wild oats also received a simulated mowing. This treatment consisted of collecting representative panicles in the "mowed" plots and storing them dry at room temperature.

Wild oats were treated at 6 different stages of growth from July 2 to July 29. On July 2, the wild oats were in the late joint stage. On July 29, the wild oats were in the late milk-early dough stage. Crops were treated at three different stages on dates corresponding to the first, fourth, and sixth stages in the wild oats. The mowing treatment was omitted in the crops.

At maturity, wild oat panicles were collected in all plots except for the simulated mowing plots in which collections had already been made. Primary florets were used in the study. Wild oat seeds were packaged in lots of 100 per plot. These seeds were obtained by sampling panicles at random from the original collection and by sampling primary florets at random up and down the panicle. The lemmas and paleas were left on the caryopses.

The crops were harvested at their respective maturities. The samples consisted of 48 feet of row per plot. Crops were threshed and cleaned before yields and test weights were determined. Crop seeds were packaged in lots of 100 per plot. Both wild oats and crop seeds were stored dry at room temperature until shortly before planting in

[4]The compound used in these studies was a sodium salt formulation of 2,2–dichloropropionic acid containing 74 percent 2,2–dichloropropionic acid equivalent and a wetting agent.

the greenhouse. At that time they were transported from Fargo, North Dakota to St. Paul, Minnesota where greenhouse tests were made.

Wild oats and crop seeds were planted ¾ inch deep in a greenhouse potting soil in metal flats and watered as needed. The greenhouse studies were conducted during the period from late February, 1957 to late May, 1957. The tests were broken into several plantings during this period. Entire replications were always planted for any given species.

RESULTS

Effect on wild oats.

Treatments with dalapon did not cause seed devitalization as occurred with applications of MH. Table 1 shows that dalapon did not greatly reduce the emergence of wild oats. However, it was noted that the 2 and 6 lb/A treatments delayed emergence approximately 1 week. Table 1 indicates that mowing as a means of preventing viable seed production probably should be completed before the wild oats are in the early milk stage.

Table 1. Percentage emergence, 2 weeks after planting, of wild oat seedlings from seeds harvested from treated parent plants.

Stage of parent plants when treated	Date of treatment	Dalapon treatment—lb/A				"Mowed"
		Check	½	2	6	
		%	%	%	%	%
Late joint	July 2	78.3	82.7	59.0	40.3	0.0
Early boot	July 6	78.0	76.7	60.7	64.0	0.0
Boot	July 9	69.3	70.7	62.0	57.0	0.0
Early head	July 13	71.0	74.7	62.0	65.7	0.3
Early milk	July 21	78.0	72.3	62.0	69.7	18.0
Late milk to early dough	July 29	80.3	73.3	64.0	55.7	53.7

Since the effect of dalapon was not that of seed devitalization, emergence counts do not reflect the degree of injury caused by the treatments. Injury shown by the emerged wild oat plants consisted of failure of plants to develop beyond the coleoptile stage or malformations of plants which were able to develop beyond the coleoptile stage. These malformations were similar to those caused by dalapon application to seedling grasses. It is difficult to express this injury in quantitative terms. An attempt is made in Table 2 which

Table 2. Number of "normal"[a] wild oat seedlings, 2 weeks after planting, per 100 seeds harvested from treated parent plants.

Stage of parent plants when treated	Date of treatment	Dalapon treatment—lb/A				"Mowed"
		Check	½	2	6	
		No.	No.	No.	No.	No.
Late joint	July 2	78.3	82.7	25.3	0.3	0.0
Early boot	July 6	78.0	76.7	17.3	0.0	0.0
Boot	July 9	69.3	66.3	8.7	0.0	0.0
Early head	July 13	71.0	71.0	21.3	0.0	0.3
Early milk	July 21	78.0	64.0	6.3	0.7	18.0
Late milk to early dough	July 29	80.3	68.7	14.3	0.3	53.7

[a]Plants which were merely stunted or slightly malformed were considered to be normal.

shows the number of "normal" wild oat plants present 2 weeks after planting in the greenhouse. Merely stunted or slightly malformed plants were counted as normal. Figure 1 represents the typical ap-

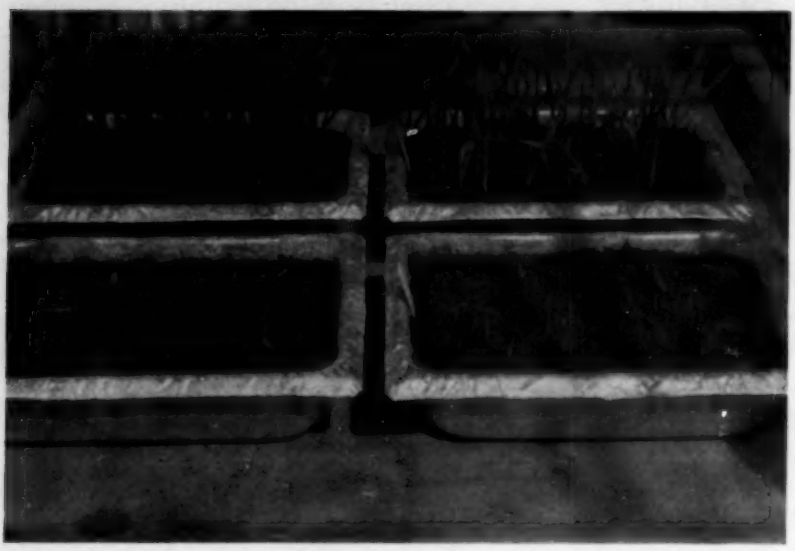

Figure 1. Plants from wild oat seeds taken from dalapon treated parent plants. Photograph taken 2 weeks after planting. Upper left, check; upper right, ½ lb/A; lower left 2 lb/A; lower right 6 lb/A. Plant growth is fairly typical of all stages studied.

pearance of the checks, ½ and 6 lb/A rates of dalapon at the stages of growth studied. It is not as typical of the 2 lb/A rate at all stages of growth studied since considerable variability existed between stages and between replicates within stages for the 2 lb/A rate. Applications of ½ lb/A were consistently ineffective, 2 lb were somewhat variable, and 6 lb were consistently effective. This seemed to indicate that the 2 lb/A rate was near the borderline between an effective and an ineffective rate.

A clearer picture of the carry-over effect in seeds from parent plants treated with dalapon is given in Figure 2 which shows the effect of the 6 lb/A rate and is very typical of all the stages studied. Most plants thus affected died without further development.

Although many of the plants from the 2 lb/A treatment outgrew the early effects of treatment, as evidenced by Table 3, it is possible that they could not have done so in the field under the stress of competition with a crop. Table 3 shows the survival of plants 5 to 6 weeks after the seeds were planted in the greenhouse. Many of the plants in the 2 lb/A rate had recovered and were growing vigorously by this time. A few of the plants from the 6 lb/A rate were still surviving but no more than 3.3 plants per 100 seeds in any stage were growing vigorously by this time. Although a few seeds from plants treated with 6 lb/A of dalapon were able to produce plants

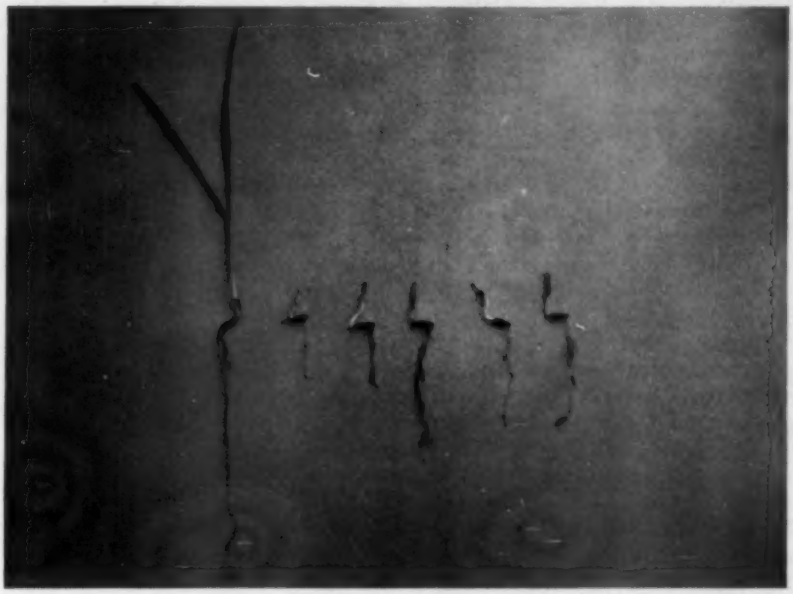

Figure 2. Effect of 6 lb/A of dalapon on wild oat plants produced from seed from treated parent plants compared with a single check at the left. Photograph taken 2 weeks after planting. Plant growth is typical of all stages studied.

Table 3. Number of wild oat plants per 100 seeds, harvested from treated parent plants, surviving 5 to 6 weeks after planting in greenhouse.

Stage of parent plants when treated	Date of treatment	Dalapon treatment—lb/A				"Mowed"
		Check	½	2	6	
		No.	No.	No.	No.	No.
Late joint	July 2	78.3	82.7	39.3	3.3	0.0
Early boot	July 6	78.0	76.7	38.7	3.7	0.0
Boot	July 9	69.3	69.3	29.7	2.7	0.0
Early head	July 13	71.0	72.3	37.3	5.0	0.3
Early milk	July 21	78.0	64.7	20.7	8.3	18.7
Late milk to early dough	July 29	80.3	71.7	32.7	4.0	53.7

which survived 5 to 6 weeks after planting in the greenhouse, it seems possible that none might have survived under competition with a crop.

It is interesting to note in Table 3 that an application of 6 pounds of dalapon gave more effective control of wild oats than a simulated mowing in the last two stages.

Effect on crop plants.

The data on crop yields in Table 4 are quite variable as evidenced by the differences between the checks from stage to stage. The yields for the plots treated with ½ lb/A rate of dalapon are recorded but will not be discussed since this rate was ineffective on wild oats at all stages.

Table 4. Yields of 3 crops treated with dalapon at three stages of growth.

Crop	Stage when treated	Date of treatment	Dalapon treatment—lb/A			
			Check	½	2	6
			Bu/A	Bu/A	Bu/A	Bu/A
Durum wheat.....	Late joint to early boot	July 2	41.4	31.2*	5.0**	0.1**
	Early head	July 13	34.2	35.8	17.4**	1.8**
	Early dough	July 29	33.0	38.2	33.3	25.0**
Spring wheat.....	Boot	July 2	35.6	38.0	27.2*	9.2**
	Head	July 13	32.4	34.8	33.4	21.5**
	Dough	July 29	40.5	36.9	35.3	34.6
Flax.....	Early bloom	July 2	19.9	23.7	17.2	7.0**
	Boll (seeds white)	July 13	19.4	22.1	20.6	9.0**
	Boll (seeds green to tan)	July 29	22.1	18.2	20.0	18.0

Ramsey durum produced an apparently satisfactory yield under the 2 lb/A dalapon treatment only at the last stage. Six lb/A nearly eliminated the yield at the first two stages and seriously reduced it at the last. Test weights (not reported in the table) of grain from the check plots averaged 61.1 lb/bu while in the 2 and 6 lb/A treatments at the last stage (early dough) they averaged 59.9 and 57.2 lb/bu, respectively. Emergence tests conducted in the greenhouse indicated that the 2 or 6 lb/A treatment very drastically injured the seeds of Ramsey durum at all three stages.

Selkirk spring wheat produced an apparently satisfactory yield under the 2 lb/A treatment at the last two stages (head and dough stage). When an application of 6 lb/A was made an apparently satisfactory yield was produced only at the last stage. Test weights of the grain harvested from check plots averaged 60.6 lb/bu while those for the 2 lb rate averaged 58.9 and 59.4 lb/bu for the head and dough stages respectively. The test weight for the grain treated at the 6 lb/A rate applied at the dough stage was 57.2 lb/bu. Emergence tests indicated very drastic injury to the Selkirk wheat seeds from application of 2 or 6 lb/A of dalapon at all three stages.

The yields of Marine flax follow the same pattern as the Selkirk spring wheat. Flax tests weights averaged 53.5 lb/bu for the check plots and 51.2, 53.0, and 53.3 lb/bu for the plots treated with the 2 lb/A rate at the first, second, and third stages. Test weights of flax seed from the 6 lb treatment in the last stage averaged 54.4 lb/bu. Emergence tests indicated that the flax seed was not injured to the same degree as were the two wheats. However, some injury resulted from the 2 and 6 lb/A rate at all three stages.

DISCUSSION

The cause of the carry-over effect in seeds from parent plants treated with dalapon is not known. One possibility could be that dalapon is translocated and stored in the seed. The data presented indicate that a rather long period existed in which applications of dalapon were able to cause the effects shown in Figures 1 and 2. In fact it would have been desirable to continue treatments at even later stages of development in wild oats. It appears that when treatments

were completed on July 29, the wild oats were still in a susceptible stage while Selkirk wheat, Marine flax, and to a lesser extent, Ramsey durum had entered a relatively tolerant stage. That is, the crops were tolerant to effects on yields but not to effects on the vitality of the seeds.

The method of wild oat control presented is in general similar to the MH method which was briefly reviewed earlier in this paper. Rates of dalapon used were higher on a pounds per acre basis than are commonly used rates of MH. MH causes devitalization of the wild oat seed whereas dalapon did not effectively reduce germination and emergence of wild oat seeds but delayed emergence and retarded or completely arrested development after emergence.

Carder (4) has reported that MH has little or no use in large scale commercial control of wild oats. He offers the five following reasons: "1. The critical timing necessary for successful treatment. 2. Treading which can only be avoided by aircraft application. 3. It must be done over a period of several years; with bad infestations possible quite a few years. 4. Its results are not readily apparent such as with some chemicals, 2,4–D for one. 5. Toxic properties, at least with currently available formulations."

The use of dalapon as herein described would also have the limitations described in points 2, 3 and 4 given above. Dalapon has a very low oral toxicity level, but it is not known whether or not residues would be a problem in applications of this type (No. 5).

In regard to critical timing (No. 1) dalapon exerted its effect on wild oats when applied over quite a span of time. It might have been effective if applied at stages later than those studied. Yields of spring wheat and flax apparently were not reduced by application of 2 lb/A of dalapon (a rate which may be on the border line between effectiveness and ineffectiveness) when applied on July 13 and July 29, a range of 16 days. Six pounds of dalapon per acre seriously reduced the yield of all three crops when applied on July 13, but apparently did not reduce yields of spring wheat and flax when applied July 29. The study did not include enough later stages in either wild oats or the crops to determine clearly the length of the period in which treatments would be effective on wild oats and yet not reduce the crop yield.

It would seem that further studies are warranted using dalapon at rates within the range of 2 to 6 lb/A at stages extending beyond those reported here.

SUMMARY

Seeds from wild oat plants treated in the field with dalapon at ½, 2 and 6 lb/A at six different stages of growth, from late joint to late milk—early dough, were studied for emergence and survival of the seedlings in the greenhouse. A simulated mowing treatment was also included. An application of ½ lb/A of dalapon was ineffective but 2 and 6 lb/A retarded emergence approximately 1 week. Seeds from wild oat plants treated with 2 lb/A of dalapon at any of the six stages produced many plants which outgrew the original retarda-

tion. Seeds from wild oat plants treated with 6 lb/A of dalapon at any stage produced very few plants which were surviving 5 to 6 weeks after planting in the greenhouse. The possibility that few if any plants from the 2 and 6 lb/A treatments could have survived the stress of competition from a crop is suggested.

Simulated mowing was an effective means of preventing viable seed production in wild oats up to the early milk stage.

Comparable treatments with dalapon on Selkirk spring wheat, Ramsey durum wheat, and Marine flax, indicated the possibility of using dalapon at certain stages to control wild oats in these crops without serious reduction in yield.

The use of dalapon for wild oat control as presented in this paper is in many ways similar to the use of MH.

Further trials with this method of using dalapon for wild oat control seem warranted. Rates within the range of 2 to 6 lb/A applied at various stages including some beyond those reported here are suggested.

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The Effect of 2,4–D on the Yield of Midland Grain Sorghum[1]

W. M. PHILLIPS[2]

SORGHUM is second only to wheat in importance in dryland crop production in the Southern Great Plains. Sorghum is planted during the season when several common annual weeds normally emerge. Proper pre-planting cultivation will often reduce the seriousness of weed infestations, but many times the crop is invaded by weeds. Under such conditions chemical weed control is of value. These studies were initiated to determine the effect of 2,4–dichlorophenoxyacetic acid (2,4–D) on the yield of weed-free sorghum.

Elder (2) reported that applications of ½, 1, and 2 lb/A of the ester and sodium salt of 2,4–D showed no differential effects on two grain and two forage varieties of sorghum treated when approximately 1 foot tall. The ½ pound rate gave a slightly increased grain yield, the 1 pound had little effect but resulted in slightly lower yields, whereas, the 2 pound rate caused serious injury and reduction in yield. Damage to the root system was noted in plots treated at all rates.

Elder and Davies (3) stated that of three forage and five grain sorghum varieties treated when 10 to 12 inches tall with ¼, ½, and 1 lb/A 2,4–D ester, only one variety, Resistant Wheatland, was seriously injured at the ½ lb/A rate. An additional variety was injured at the 1 lb/A rate, while reductions in yields of other varieties were only slight at the 1 lb/A level.

Barrons (1) reported that sorghum was less severely injured with an amine salt of 2,4,5–T than with an amine salt of 2,4–D. He also found damage to the root system as evidenced by malformations and the formation of adventitious roots following spraying with 2,4–D.

Hay, et al. (7) treated three varieties of sorghum with ¾ lb/A of an ethyl ester of 2,4–D at 15 stages of growth and reported the three varieties did not reach the most susceptible stages of growth simultaneously. They indicated that yields were generally lower for early treatments.

Phillips (10) stated that treatment with 2,4–D resulted in the retardation of the sorghum root system as evidenced by ease of pulling the treated plants and by digging and examining the root system. The injury to the root system was greater with the heavier rates of application.

Shafer, et al. (11) found that 2,4–D treated sorghum plants were shorter and headed later. Greatest effect occurred when the plants were in the 10-leaf stage when treated. They also reported sterile spikelets in those portions of the head that were flowering at the time of treatment.

[1]Contribution No. 118, Ft. Hays Branch, Kans. Agr. Exp. Sta., Hays, Kans. Crops Research Division, ARS, USDA and Kans. Agr. Exp. Sta., cooperating.

[2]Research Agronomist, Crops Research Division, ARS, USDA, and Assistant Professor, Kans. Agr. Exp. Sta., Hays, Kans.

Gassaway, et al. (8) treated 10 sorghum varieties with an ester of 2,4–D and reported that all varieties showed characteristic 2,4–D root damage in proportion to the rate of dosage. However, they indicated that the damage was more noticeable on some varieties. They also reported a decrease in height of the more susceptible varieties, but only slight reduction in yield as a result of any of the treatments. They also studied the pounds of force necessary to pull sorghum plants from the soil and found that, for the more susceptible varieties, considerably less force was required to pull the treated plants than the untreated.

Elder et al. (6) sprayed six varieties of grain sorghum with 2,4–D, 2,4,5–T, and MCPA. The treatments were applied when the crop was 12 to 15 inches tall. They found that all treatments caused brace root deformation. MCPA was more damaging to the crop than 2,4–D but 2,4,5–T amine was less injurious than 2,4–D. The ¼ and ½ lb/A rates of 2,4–D ester did not affect the yield of any of the sorghum varieties tested. Elder et al. (5) reported one variety appeared to be susceptible to 2,4–D, 2,4,5–T, and MCPA when treated during extremely hot, dry weather. Other varieties were not affected by rates up to 1 lb/A.

Gassaway et al. (9) noted little brace root fasciation as a result of spraying 10 different varieties with an isopropyl ester of 2,4–D and 2,4,5–T, or a butoxy ethanol ester of MCPA at rates of ¼, ½, and 1 lb/A. They reported that 1 lb/A retarded exsertion of the heads in all varieties and caused from one to three days delay in head emergence and flowering in all varieties. The effect of the three chemicals was similar, with the 1 pound rate of 2,4–D causing somewhat more damage than 1 pound of 2,4,5–T. Rates of less than 1 lb/A of 2,4–D had no effect on the grain yield. They found no difference in test weight as result of the various treatments.

Elder et al. (4) sprayed six combine varieties and four forage varieties with ½ lb/A of an amine salt of 2,4–D or 1 lb/A of an ester form of 2,4–D, 2,4,5–T, and MCPA. They reported typical brace root injury but no effect on the grain or forage yield. Some varieties were retarded in maturity by 1 lb/A of an ester of 2,4–D or MCPA.

Wiese and Rea (12, 13) applied an amine salt of 2,4–D to Redbine–60 sorghum at several stages of growth. Greatest yield reductions occurred following treatments made during flowering. They report that 2 lb/A of 2,4–D did not always cause yield reductions and less than 0.5 pound did not affect grain yields.

MATERIALS AND METHODS

Experiments were conducted in 1950, 1952, 1953, and 1954. Plantings were made in 1955 and 1956 but severe drought caused crop failure in both years. Each year Midland grain sorghum was planted with field machinery and, after emergence, plots were laid out so that each plot was composed of four rows, 25 feet long. Weed control was accomplished by shallow cultivation and hand weeding. All four rows were sprayed and the two center rows were harvested. The

experimental design was a randomized block with three replications in 1950 and four replications in the other years.

Spray applications were made with a compressed air sprayer mounted on a garden tractor. The speed of the tractor was calibrated so that a volume of 20 gallons per acre was applied. A constant pressure of 30 psi was maintained. An alkanolamine salt and an isopropyl ester of 2,4–D were used in all experiments. Both formulations were applied at 0.13, 0.25, 0.50, and 1.0 pound 2,4–D acid equivalent per acre in 1950, 1953, and 1954. The same treatments were applied in 1952 except the 0.13 pound rate was not used. No-treatment plots were included in all experiments.

Separate plots were treated at three different stages of growth. The first treatment in each year was made when the sorghum plants had from 5 to 7 leaves and were approximately 6 inches tall. The second treatment was applied when the crop had 9 to 11 leaves. Considerable variation in height was noted between years, but in all cases the second treatment was made shortly after the floral parts became readily visible following simple dissection in the field. The average length of the developing heads at time of treatment was one inch. The third treatment was applied while the sorghum plants were pollinating. A hail storm August 1, 1954, severely damaged the sorghum and prevented treatment at the third stage.

Table 1 gives the dates of 2,4–D application for each year, together with some information on rainfall and general crop condition at the time of treatment. Although rainfall is important, it is, of course, only one of several climatic factors which effect crop production.

Table 1. Dates of 2,4-D application and precipitation amounts before and after treatment.

Year	Date of treatment	Stage of growth	Precipitation—inches				Crop condition when treated
			Before treatment		After treatment		
			5 days	21 days	5 days	21 days	
1950	6-29	5–7 leaf	0.60	1.00	0.15	2.44	Fair
	7-13	9–11 leaf	0.53	2.72	0.17	3.98	Good
	8-16	Pollinating	2.22	7.18	0.41	2.29	Excellent
1952	7-8	5–7 leaf	0.10	0.27	0.17	1.77	Fair
	7-26	9–11 leaf	1.23	1.87	0.00	1.28	Fair
	8-16	Pollinating	0.34	1.28	0.28	0.74	Fair
1953	6-22	5–7 leaf	0.02	1.05	0.23	6.46	Good
	7-15	9–11 leaf	3.32	6.23	0.30	1.12	Excellent
	7-29	Pollinating	0.00	4.70	0.54	2.67	Excellent
1954	7-1	5–7 leaf	0.03	1.22	0.00	0.56	Good
	7-27	9–11 leaf	0.11	0.67	0.39	2.16	Fair

Therefore, rainfall prior to the time of treatment and crop condition are not necessarily closely correlated. Precipitation during the growing seasons of 1952, 1953, and 1954 was below average in the Hays, Kansas, area. However, moisture in the soil at seeding time and favorable distribution of rainfall combined to prevent the crop from showing serious drought stress. Above average rainfall was received during the 1950 growing season.

RESULTS AND DISCUSSION

In each of the four years treatments with 0.25 pound or more 2,4–D per acre applied at the early stage of crop development caused fasciation of the brace roots and delayed development of the feeder roots. This condition is illustrated in Figure 1. These effects did

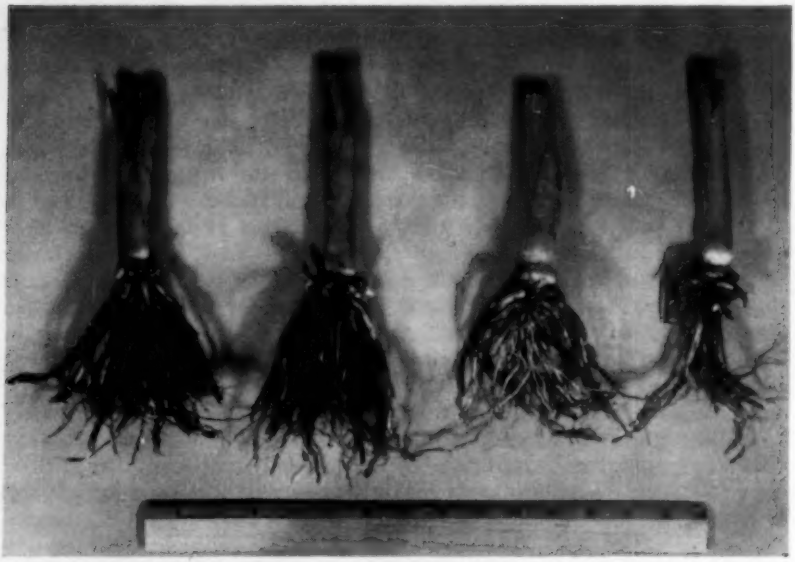

Figure 1. Roots of Midland sorghum 17 days after foliage applications of 2,4–D ester. Left to right: no treatment, 0.25, 0.50, 1.0 pound 2,4–D per acre, applied at the 5–7 leaf stage of crop development.

not appear to reduce yields seriously, especially at the lower rates, and if sufficient moisture was available to sustain the plant during the 3- to 5-week period necessary for recovery.

Applications made during the 9- to 11-leaf stage often interfered with development of the head and flower parts. Plants treated in this stage often produced tillers late in the season, but the tillers contributed little to the yield of the crop.

1950 Experiment.

Analysis of yields showed a highly significant rate x stage interaction. No other interactions involving formulation, rate, and stage were significant. Figure 2 gives data on yields obtained from the various rates of 2,4–D ester and amine combined at the three treatment stages. When chemical was applied at the 5- to 7-leaf stage, only the 1 lb/A rate significantly reduced yields below no treatment. Treatments of ½ and 1 lb/A at the second stage, 9 to 11 leaves, caused substantial yield reductions. When applied during pollination, all rates of 2,4–D reduced sorghum yields below no treatment, but differences between rates were small.

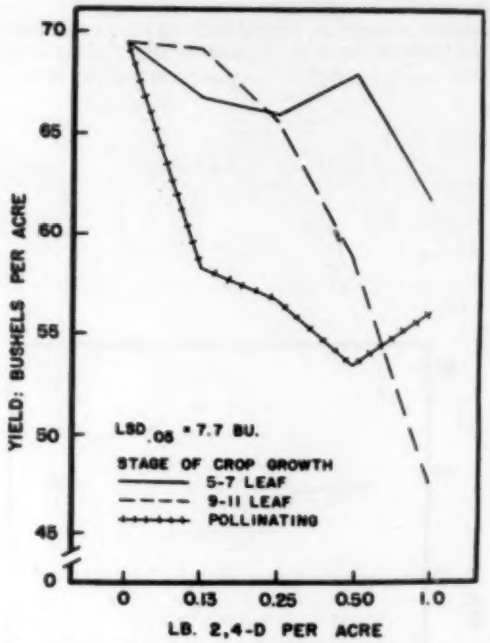

Figure 2. Mean yield of Midland sorghum as affected by time and rate of application of an ester and an amine salt formulation of 2,4–D, 1950.

1952 Experiment.

As shown in Figure 3 the yield pattern resulting from treatments at the 5- to 7-leaf and 9- to 11-leaf stages was similar to that obtained in the 1950 experiment. Sorghum treated at the 5- to 7-leaf stage with 1 lb/A 2,4–D yielded significantly less than the no treatment plots. Other rates did not cause significant yield reductions when applied at the early stage of crop development. As in 1950, the crop was susceptible to chemical injury when treated in the 9- to 11-leaf stage. One-half pound 2,4–D per acre reduced yields below both the no treatment and the 0.25 pound rate. One pound caused additional reduction. Chemical applications made during pollination did not lower yields, except at the 1 lb/A rate.

In 1952 there was a significant formulation x stage interaction. Table 2 shows the average yields obtained from plots treated with the two formulations at three stages. All rates were combined to give the formulation-stage average. It is evident that, in 1952, the ester formulation of 2,4–D was largely responsible for the yield reductions resulting from treatment during the 9- to 11-leaf stage.

Table 2. Mean yields of sorghum treated with all rates of an ester or an amine salt formulation of 2,4-D at three stages of growth.

Stage when treated	Yield—bu/A			
	1952		1953	
	2,4-D ester	2,4-D amine	2,4-D ester	2,4-D amine
5–7 leaf	36.7	36.3	67.1	72.2
9–11 leaf	30.7	36.3	61.2	51.5
Pollinating	35.4	37.4	68.8	72.7
LSD 5% level	3.1		4.2	

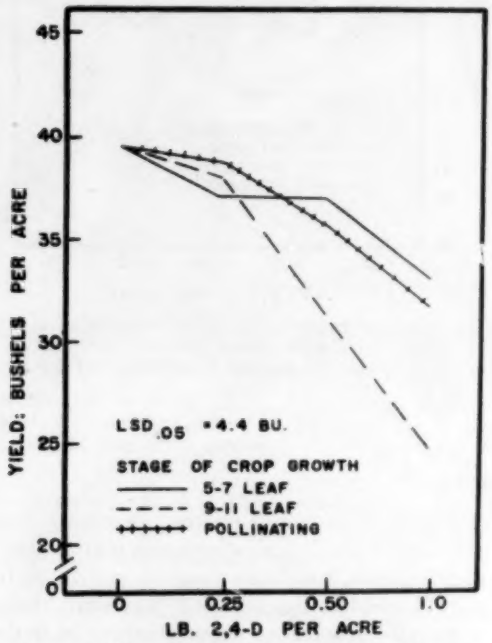

Figure 3. Mean yield of Midland sorghum as affected by time and rate of application of an ester and an amine salt formulation of 2,4–D, 1952.

1953 Experiment.

The interaction of formulation x stage was significant again in 1953, but as shown in Table 2, the amine formulation of 2,4–D applied at the 9- to 11-leaf stage had the greatest effect on yields.

Figure 4 gives the yield curves for rates and stages in 1953. None of the rates applied when the sorghum had 5 to 7 leaves significantly affected yield. When the sorghum was treated in the 9- to 11-leaf

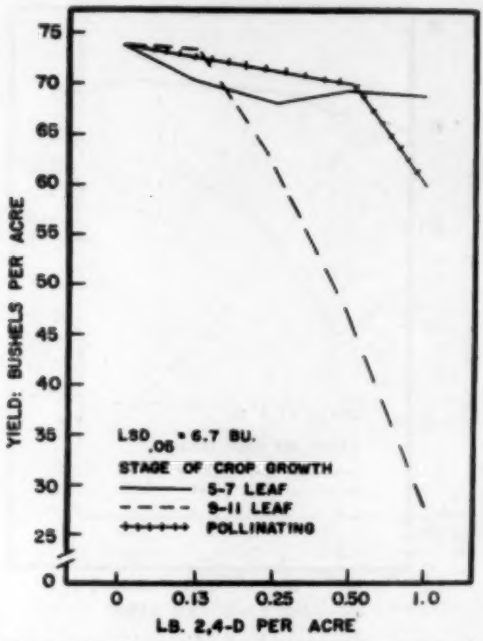

Figure 4. Mean yield of Midland sorghum as affected by time and rate of application of an ester and an amine salt formulation of 2,4–D, 1953.

stage, 0.25, 0.50, and 1.0 lb/A 2,4–D reduced yields progressively as the rate increased. One pound per acre applied during pollination caused lower yields but other rates did not.

1954 Experiment.

Yields given in Figure 5 are low due to hail damage. Treatments were applied when the crop had 5 to 7 leaves and 9 to 11 leaves, but the treatment during pollination was omitted because of the hail damage. None of the rates affected yields significantly when applied at the 5- to 7-leaf stage. Yields from plots treated in the 9-11-leaf stage were reduced by all rates.

Effect of Formulation on Yield.

Figure 6 shows combined average yields for 1950, 1952 and 1953 following treatment at three stages of growth with an ester and an amine salt of 2,4–D. When the three-year average is considered it appears that the two formulations of 2,4–D caused essentially the same reaction in sorghum. Large yield reductions following treatment at the 9- to 11-leaf stage with 2,4–D ester in 1952 and 2,4–D amine in 1953 cannot be fully explained from the data presented. Differences in growing conditions may be pointed out, (Table 1)

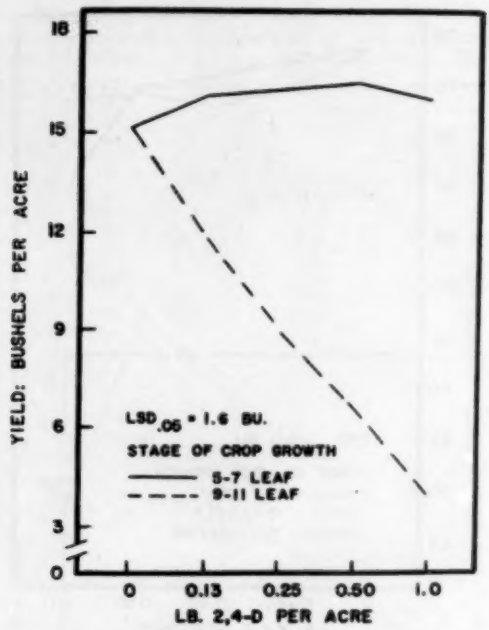

Figure 5. Mean yield of Midland sorghum as affected by time and rate of application of an ester and an amine salt formulation of 2,4–D, 1954.

but until more data are available no conclusion can be reached concerning the relationship between these conditions and the effect of formulation on yield. Figure 6 also illustrates the marked reduction in sorghum yield caused by treatment during the 9- to 11-leaf stage of development.

Summary and Conclusions

1. Weed-free Midland grain sorghum was sprayed with ester and amine salt formulations of 2,4–D in 1950, 1952, 1953, and 1954. The crop was treated with 0.13, 0.25, 0.50, or 1.0 pound 2,4–D acid equivalent per acre of each formulation at three different stages of development. The stages were (a) 5- to 7-leaf, (b) 9- to 11-leaf or early floral development, and (c) pollinating.

2. When treated in the 5- to 7-leaf stage, crop yields were not reduced with less than 1 lb/A 2,4–D, and in 2 of the 4 years there were no significant differences in the yields. However, root injury was most serious following treatment during this stage.

3. Yields of sorghum from plots treated in the 9- to 11-leaf stage were consistently the most severely reduced by 2,4–D treatments. Rates of 0.50 and 1.0 lb/A 2,4–D reduced yields in all years. In 1953 and 1954, even the low rate of 0.25 pound caused yield reduction.

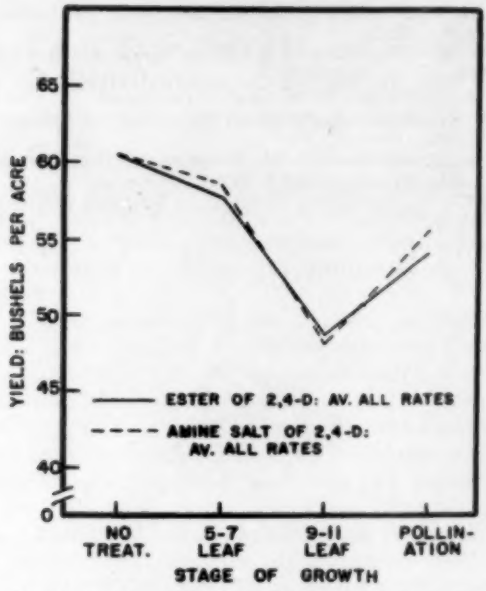

Figure 6. Mean yield of Midland sorghum for 1950, 1952 and 1953 as affected by formulation of 2,4–D and by stage of growth when treated.

4. Treatments applied while the crop was pollinating were damaging in 1950, but in 1952 and 1953 only the 1 lb/A rate reduced yields significantly.

5. No consistent differences in the effect of the two formulations on yields could be determined.

6. None of the treatments caused significant increase in yield.

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The Effect of Soil Type, Soil pH, and Simulated Rainfall on the Distribution of DNBP in the Soil[1]

CLYDE DOWLER, N. M. BAUGHMAN and COLLINS VEATCH[2]

A RELATIONSHIP has been noted between environmental conditions, including soil characteristics, and the movement, persistence and activity of herbicides applied to the soil. Field studies have often given differing, and sometimes contradictory results, possibly because of different environments. Empirical studies cannot fully explain these differences.

Some soil conditions affecting the activity of chemicals used as herbicides have been studied. Hanks (6) reported that soils treated with 2,4–D and leached with 16 inches of water were less toxic to plant growth than those leached with 10 inches of water. Davis, Selman and Davis (4), Davis and Selman (3), and Dowler and Baughman (5) found that the leaching of DNBP was directly proportional to the amount of water applied, and that the amount of leaching varied with soil type.

Kries (9) and Hanks (6) found that limed or naturally alkaline soils appeared to retain 2,4–D toxicity for a longer time than unlimed soils. Davis and Davis (2) and Hollingsworth (8) reported that the vapor injury to plants from DNBP was prevented in soils of high lime content or in those soils in which the surface layer was neutral or alkaline in reaction. Dowler and Baughman (5) reported that chemical recovery of DNBP from the soil increased as the pH of the soil was raised from pH 5 to pH 7.

Dallyn et al. (1) reported that, in general, organic matter content of the soil was the most important soil characteristic affecting the activity of herbicides applied to the soil and overshadowed most of the organic matter x treatment interactions. Hernandez and Warren (7) found that leaching of 2,4–D increased with decreasing organic matter content of soils.

This paper reports part of an investigation designed to determine (1) the effect of soil type, soil pH, and simulated rainfall on the herbicidal activity of an alkanolamine salt of 4,6–dinitro *o* secondary butylphenol (DNBP) on corn and soybeans grown in the greenhouse, and (2) the movement and persistence of the chemical in the soil as measured by the elongation of radicals of soybean seeds planted in seeding bands filled with soil from different layers of treated flats.

MATERIALS AND METHODS

The soils used in this experiment were obtained from three sources: Wharton silty clay loam from the West Virginia University

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[2]Formerly Graduate Assistant, now Research Assistant, Agronomy Dept., Ohio State University, Columbus, Ohio; and Associate Agronomists, respectively, West Virginia Agr. Expt. Sta., Morgantown, West Virginia.

Agronomy Farm at Morgantown, West Virginia; Pope sandy loam from the Experimental Farm at Reedsville, West Virginia; and Monongahela sandy loam from the Reymann Memorial Farms at Wardensville, West Virginia. Table 1 shows the results of chemical and physical analyses made to characterize these soils.

Table 1. Chemical and physical analyses of soils used in this study.

Soil component	Unit of measurement	Soil		
		Wharton	Pope	Monongahela
Sand (.05 mm)	%	17.00	70.06	68.24
Silt (.05–.002 mm)	%	48.30	17.09	17.65
Clay (.002 mm)	%	34.70	12.85	14.11
Moisture equivalent	%	23.50	13.00	8.14
Organic matter	%	2.07	2.47	0.92
Phosphorus (Truog)	lbs/A	196.00	208.80	136.80
Cation exchange capacity	me/100 gms	12.63	9.60	7.80
Original pH level	—	6.40	5.40	6.00

The soils were brought to the greenhouse, air dried, screened through 1/4 inch mesh screen, and thoroughly mixed. The reaction of individual lots of each soil was adjusted to pH 5, pH 6, and pH 7, by the addition of sulfuric acid or lime, according to buffer curves for each soil. The soil was then mixed, moistened and allowed to stand for 2 weeks to reach equilibrium. The pH determinations made at the conclusion of the experiment showed that the reaction of individual flats did not vary more than 0.4 of a pH unit from that desired.

Growth studies were made using perforated galvanized metal flats filled with soil to a depth of 2½ inches. A thin layer of glass wool was placed in the bottom of each flat to prevent loss of soil and permit adequate drainage. Twelve kilograms of the Pope and Monongahela soils and 11 kilograms of the Wharton soil were used respectively. The soils were moistened by sub-irrigation and allowed to dry to the moisture equivalent. Twenty seeds each of corn and soybeans were planted at a depth of 1½ inches in each flat. DNBP at the rate of 6 pounds per acre was applied immediately after planting. Each treatment was replicated three times. An experimental greenhouse sprayer (10) was used to apply the herbicide.

Twenty-four hours after the application of the herbicide, distilled water as simulated rainfall was applied at rates of 0, 1/4, 1/2 and 1 acre inch. A Hudson hand sprayer having a capacity of 2½ gallons was adapted to the experimental greenhouse sprayer for application of the simulated rainfall.

The heights of the corn and soybean plants were measured at the age of 2 weeks to determine the effect of treatment.

Three days after the application of simulated rainfall, samples of soil were removed from each replication at four depths: 0 to 1/4, 1/4 to 3/4, 3/4 to 1¼, and 1¼ to 2½ inches. The surface area sampled was 77 square inches. The soil samples were well mixed and 300 grams of each sample was placed in seeding bands and 10 soybean seeds were planted. The soybean seeds were removed after 6 days

and the length of the radicles measured to give a biological determination of active DNBP.

RESULTS

Growth of corn and soybeans in flats of DNBP treated soil.

The three variables, soil type, soil pH, and amounts of simulated rainfall, exerted highly significant effects on the height (measured at 2 weeks) of corn and soybean plants. Figure 1 shows the representative growth of corn and soybeans in one test of the experiment.

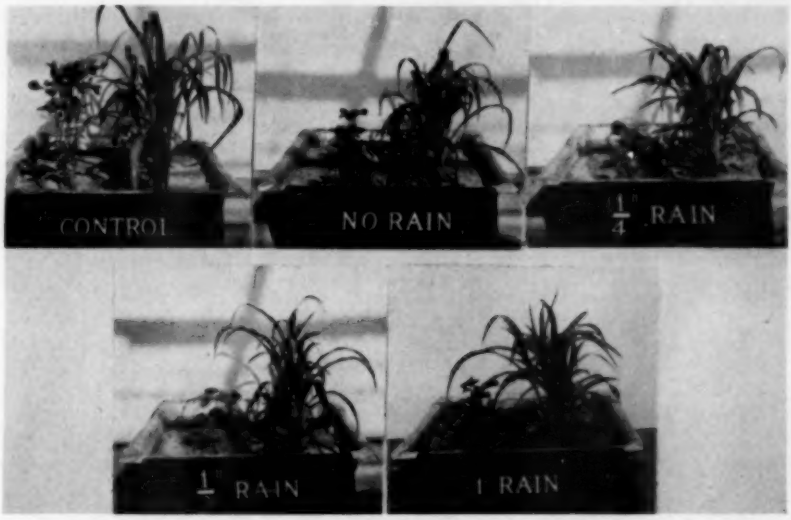

Figure 1. Growth of corn and soybeans in Monongahela silt loam at pH 6.0 2 weeks after treatment with DNBP pre-emergence spray at 6 lb/A on all plots except the control.

The interactions, soil x pH, rainfall x pH, and rainfall x soils x pH were highly significant for corn. For soybeans, soil x pH was not significant at the 5% level. These data substantiate the postulate made earlier that the herbicidal activity of DNBP may be affected by soil type and soil reaction. Leaching by rainfall will be modified by soil type and soil reaction which effects the persistence or residual activity of the chemical.

The average heights of plants for soils and pH levels averaged over all rainfalls are presented in Table 2. The heights of the plants are also expressed as a percentage of the control (no DNBP) flats. These data show that the least effect occurred in the Pope soil for both corn and soybeans. The greatest effect on soybeans occurred in the Monongahela soil followed by the Wharton soil. For corn there seemed to be little difference between the Monongahela and Wharton soils.

The effect of simulated rainfall averaged over all pH levels and expressed as a percentage of the control plants is shown in Table 3.

Table 2. The height of corn and soybean plants at 2 weeks, grown in soils treated with DNBP at 6 lb/A as affected by soil pH and soil type.

Soil pH	Corn			Soybeans		
	Treat. means inches[a]	Control means inches[b]	Treat. pct. of control	Treat. means inches	Control means inches	Treat. pct. of control
			Wharton soil			
5	14.33	15.69	91.5	3.79	5.57	68.0
6	14.14	17.11	82.7	3.64	5.94	61.3
7	13.11	14.33	91.5	4.27	5.33	80.7
Mean	13.86	15.71	88.6	3.90	5.61	70.0
			Monongahela soil			
5	15.25	16.10	94.7	3.28	4.60	71.3
6	10.32	14.68	70.3	2.63	7.43	35.4
7	14.61	14.53	100.5	4.59	5.12	89.6
Mean	13.39	15.10	88.5	3.50	5.72	65.4
			Pope soil			
5	18.29	19.96	91.6	6.23	8.56	72.8
6	20.36	24.21	84.1	6.94	8.48	81.8
7	23.26	24.11	96.5	7.88	9.38	83.5
Mean	20.64	22.76	90.7	.02	8.81	79.4

[a]Represents averages of 3 replications of each of 4 rainfall levels.
[b]Represents average of 3 replications.

Table 3. The heights of corn and soybean plants at 2 weeks, grown in soil treated with DNBP at 6 lb/A as affected by simulated rainfall.

Rainfall inches	Corn		Soybeans	
	Treat. means inches	% of Control	Treat. means inches	% of Control
		Wharton soil		
0	14.93	95.0	5.17	92.2
¼	13.62	86.7	3.50	62.3
½	13.01	82.8	3.52	62.7
1	13.87	88.3	3.41	60.7
Mean	13.86	88.2	3.90	69.5
Control	15.71		5.61	
		Monongahela soil		
0	14.29	94.5	4.22	74.0
¼	13.09	86.7	3.35	58.6
½	13.15	87.2	3.28	57.5
1	13.05	86.5	3.17	55.4
Mean	13.39	88.7	3.50	61.3
Control	15.10		5.72	
		Pope soil		
0	21.54	94.7	7.11	80.6
¼	20.41	90.0	7.23	82.0
½	20.30	89.4	6.41	73.0
1	20.30	89.4	6.74	76.5
Mean	20.64	90.8	7.02	79.8
Control	22.76		8.81	

These data show some reduction in the heights of corn and soybeans on DNBP-treated soil when no rainfall was applied. The effect appeared to be greater for soybeans than for corn. Rainfall of ¼ inch or more caused the herbicide to retard the growth of both corn and soybeans.

Growth of soybean radicles in DNBP treated soil.

The presence of DNBP in soil could be readily detected by a reduction in germination and a reduction of the length of radicles of soybeans planted in seeding bands filled with soil from DNBP-treated flats. The effect of simulated rainfall on the movement of DNBP downward in the soil could be followed by a reduction in length of soybean radicles in soil from different depths. Figure 2

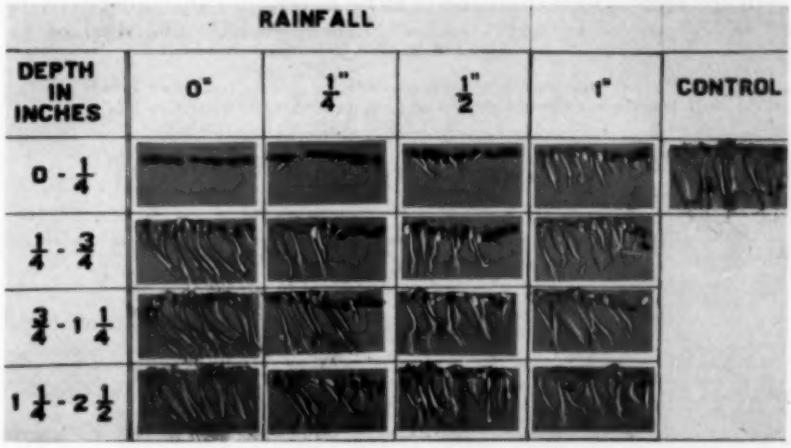

Figure 2. Growth of soybeans in seeding bands of Monongahela silt loam from several depths at pH 6.8 treated with DNBP at 6 lb/A.

shows this clearly for the Wharton soil at pH 6.8. The data, expressed as the average length of 30 soybean radicles in inches for all soils at all pH levels, are presented in Table 4.

There was no germination of soybeans in the soil from the surface ¼ inch of DNBP-treated flats where no rainfall was applied. This was true for all soils at all pH levels. Some movement of the herbicide into deeper layers of the soil occurred where no rainfall was applied but the amount seemed to be a function of pH and soil type. The data in Table 4 indicate that not enough of the herbicide moved downward in the Wharton soil to cause a significant reduction in radicle length at any pH level. However, for the Pope soil significant movement occurred at pH 5 and for the Monongahela soil at pH 5 and pH 7.

DISCUSSION

DNBP appears to increase in volatility with increasing acidity (2, 4, 5, 8). The presence of the herbicide at depths below the surface

in porous sandy soils can be explained on the basis of gaseous diffusion. Likewise, the reduced movement in the heavier textured Wharton soil can be explained by a lowered rate of diffusion. Either the presence of excess moisture or error in sampling may be proposed as the cause for the presence of DNBP below the surface layer in the very sandy Monongahela soil at pH 7.

Movement of DNBP, in significant amounts, to lower soil levels occurred where simulated rainfall was applied. These data are shown in Table 4. No exact relationship between amounts of rainfall and movement of the chemical, as indicated by reduction in radicle length, could be shown for the entire experiment. The amount of movement seems to be as much a function of soil type and soil reaction as of the amount of rainfall applied.

In the lighter soils there seems to be a trend for increased activity of DNBP in lower layers and an overall greater effectiveness in

Table 4. The average length of soybean radicles grown in seeding bands filled with soil from different depths of flats treated with 6 lb/A of DNBP.

Soil type	pH	Depth of sample inches	Radicle length—inches				
			Rainfall—inches				Control
			0	¼	½	1	
Wharton	5	0–¼	0.00*	0.68*	1.12*	1.42*	3.70
		¼–¾	3.70	3.21	3.17	3.48	
		¾–1¼	3.58	3.32	3.28	3.19	
		1¼–2½	3.25	3.47	3.30	3.27	
		Mean	2.63	2.67	2.72	2.84	
		% of Control	71.2	72.2	73.5	77.0	
Wharton	6	0–¼	0.00*	0.32*	0.34*	0.68*	2.57
		¼–¾	2.48	2.08	1.66*	2.08	
		¾–1¼	2.53	2.45	2.45	1.98	
		1¼–2½	2.62	2.15	2.30	2.30	
		Mean	1.91	1.75	1.69	1.76	
		% of Control	74.3	68.1	65.7	68.5	
Wharton	7	0–¼	0.00*	0.08*	1.43*	1.44*	2.33
		¼–¾	2.60	2.92	2.55	2.49	
		¾–1¼	2.44	2.79	2.85	2.43	
		1¼–2½	3.12	3.27	2.60	2.70	
		Mean	2.04	2.26	2.36	2.26	
		% of Control	87.6	96.9	101.3	96.9	
Monongahela	5	0–¼	0.00*	0.20*	0.23*	0.35*	2.06
		¼–¾	1.53*	1.41*	1.70	1.53*	
		¾–1¼	1.70	1.55*	2.03	1.56*	
		1¼–2½	1.28*	1.38*	2.13	1.90	
		Mean	1.13	1.13	1.52	1.33	
		% of Control	54.8	54.8	73.7	64.5	
Monongahela	6	0–¼	0.00*	0.08*	0.48*	0.51*	2.53
		¼–¾	1.93	1.66*	1.23*	0.48*	
		¾–1¼	2.31	2.39	1.76*	1.03*	
		1¼–2½	2.28	2.13	2.48	1.55*	
		Mean	1.63	1.56	1.49	0.89	
		% of Control	64.5	61.7	58.9	35.2	

*Differs significantly from control at 5% level.

Table 4. Concluded.

Soil type	pH	Depth of sample inches	Radicle length—inches				Control
			Rainfall—inches				
			0	¼	½	1	
Monongahela	7	0–¼	0.00*	0.19*	0.62*	1.07*	4.00
		¼–½	2.95*	1.11*	1.39*	1.96*	
		½–1¼	3.21	2.39*	2.18*	2.44*	
		1¼–2½	3.23	2.07*	2.29*	2.73*	
		Mean	2.35	1.44	1.62	2.05	
		% of Control	58.8	36.0	40.5	51.3	
Pope	5	0–¼	0.00*	0.53*	0.82*	0.91*	3.22
		¼–½	1.93*	2.48*	2.09*	2.37*	
		½–1¼	2.32*	2.43*	2.22*	2.07*	
		1¼–2½	2.69	2.53*	2.45*	2.39*	
		Mean	1.73	1.99	1.89	1.93	
		% of Control	53.7	61.8	58.7	59.9	
Pope	6	0–¼	0.00*	0.28*	1.03*	2.05*	4.24
		¼–½	4.30	4.62	3.82	3.65	
		½–1¼	4.83	4.11	4.40	4.20	
		1¼–2½	4.60	4.42	4.38	4.42	
		Mean	3.43	3.36	3.41	3.58	
		% of Control	81.0	79.3	80.5	84.5	
Pope	7	0–¼	0.00*	0.58*	0.99*	1.33*	3.34
		¼–½	3.22	3.03	2.94	2.37*	
		½–1¼	3.19	3.18	2.76	2.49*	
		1¼–2½	3.48	2.95	3.08	2.47*	
		Mean	2.47	2.43	2.44	2.16	
		% of Control	74.0	72.8	73.1	64.6	

*Differs significantly from control at 5% level.

reducing radicle length with an increase in rainfall. This trend is, however, modified by the soil reaction. In the Monongahela soil there was no definite trend in modification of radicle length at pH 5.0. In the Pope soil at pH 6.0, there was no significant reduction in radicle length when the soil samples were taken from below the top ¼ inch of soil.

The distribution of the herbicide throughout the soil as measured by its effect on radicle length is shown in Table 4. More movement and a greater overall effect of DNBP was evident on the Monongahela followed by the Pope with the smallest effect appearing on the Wharton soil. This is in the same order of increasing colloid content of the three soils.

The effect of pH on herbicidal activity of the chemical is not so apparent. The percentage of elongation of the radicles averaged over all soils is 62.4, 68.5, and 71.2 percent for pH 5, 6, and 7 respectively, indicating that some reduction in the activity of DNBP occurs as the reaction of the soil approaches neutrality. However, the pH at which greatest effect was found varied with soil type, being pH 7 for the Monongahela, pH 5 for the Pope, and pH 6 for the Wharton soil.

In soybeans, the more sensitive crop, a marked effect of soil type

on the herbicidal activity of the chemical was detected. The effect was greatest on the Monongahela silt loam, a light textured soil low in organic matter, and least on the Pope silt loam, a light soil fairly high in organic matter. This is in agreement with previous reports that increases in organic matter will lower the herbicidal activity of the chemical.

SUMMARY

Soil type, pH levels, and rainfall were found to affect the distribution and activity of DNBP as indicated by soybean germination and soybean radicle growth in soil taken at different depths from DNBP treated flats.

The growth of corn and soybeans on DNBP treated soil was modified by soil type, pH, and rainfall. There was an inverse relationship between herbicidal effectiveness and soil organic matter content.

DNBP was less effective when applied to soils at pH 7 than on soils of more acid reaction.

Movement and increased activity of the herbicide occurred when rainfall was applied to DNBP treated soils.

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Chemical Control of Rabbitbrush with Emphasis upon Simultaneous Control of Big Sagebrush[1]

D. N. Hyder, F. A. Sneva, D. O. Chilcote, and W. R. Furtick[2]

Only a few reports have been published on the susceptibility of rabbitbrush *(Chrysothamnus* spp.) to chemical herbicides (1, 2, 5, 6, 7). From these publications the following conclusions may be made: (a) 2,4–D (2,4–dichlorophenoxyacetic acid) is more effective on rabbitbrush than 2,4,5–T (2,4,5–trichlorophenoxyacetic acid), (b) June applications are generally best, (c) rabbitbrush is more tolerant to growth regulators than big sagebrush *(Artemisia tridentata),* and (d) resprouting from the stem base is common.

A great deal of demand for more information has been expressed. Variations in kill from extremely poor to very good have caused special concern about timing of spray applications. The need for and value of rabbitbrush control is largely empirical.

The present paper is a compilation of mortality results from five experiments on green (or Douglas) and grey (or rubber) rabbitbrush *(C. viscidiflorus* and *C. nauseosus),* and big sagebrush. These experiments were conducted in central and southeastern Oregon, and included various dates of application, herbicides, and acid rates. The results obtained support previous publications and offer new information on the chemical control of rabbitbrush. In particular the results provide new information on the timing of spray applications to obtain simultaneous control of rabbitbrush and big sagebrush in mixed stands.

Materials and Methods

Spraying trials were made in 1950, 1954, and 1955. A compressed-air back-pack sprayer employing a single 8001 nozzle under a pressure of 35 psi was used in four trials, and a jeep-mounted power sprayer employing a 13-foot boom mounted with 8001 nozzles under a pressure of 30 psi was used in one trial. Applications were made at solution volumes of 5 to 10.9 gal/A, at acid rates from 0.5 to 4.0 lb/A, and on various dates throughout the growing season. Further details are included in the discussion of results of individual experiments.

The herbicides included were as follows:

(a) 2,4–D butoxy ethanol ester,
(b) 2,4–D butyl ester,
(c) 2,4–D methoxy polyethylene glycol 350 ester (2,4–D MPGE),
(d) 2,4–D propylene glycol butyl ether ester (2,4–D PGBE),

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[2]Range Conservationists, Crops Research Division, A.R.S., U.S.D.A., and Research Assistants, Oregon Agricultural Experiment Station, respectively.

(e) 2,4–D sodium salt,
(f) 2,4,5–T butoxy ethanol ester,
(g) 2,4,5–T propylene glycol butyl ether ester (2,4,5–T PGBE),
(h) 2,4,5–T and 2,4–D isopropyl esters in 1:1 mix,
(i) 2–methyl–4–chlorophenoxyacetic acid (MCPA) as a butoxy ethanol ester,
(j) 4–chlorophenoxacetic acid (4–CPA) as a butoxy ethanol ester,
(k) 3,4–dichlorophenoxyacetic acid (3,4–DA) as an iso–octyl ester,
(l) 2,3,6–trichlorobenzoic acid (2,3,6–TBA) as a sodium salt,
(m) 2–(2,4,5–trichlorophenoxy) propionic acid (silvex) as a butoxy ethanol ester,
(n) 2–(2,4,5–TP) propylene glycol butyl ether ester (silvex PGBE), and
(o) 3–amino–1,2,4–triazole (amitrol).

All live brush plants were counted on each plot before spraying and again one year after spraying to determine mortality in most trials.

RESULTS

Screening trials on rabbitbrush species.

Screening trials on green and grey rabbitbrush were conducted in 1954 using the following materials: 2,4–D butoxy ethanol ester, 2,4,5–T butoxy ethanol ester, MCPA butoxy ethanol ester, 4–CPA butoxy ethanol ester, 3,4–DA iso–octyl ester, 2,3,6–TBA sodium salt, silvex butoxy ethanol ester, and amitrol. All materials were applied at the rate of 3 lb/A on plots 0.5 square rod in size using a back-pack sprayer. The plots were arranged in three randomized blocks on each species of rabbitbrush. Spraying was accomplished on June 5, 1954, and ocular estimates of mortality were made on July 25, 1955. Independent estimates were made of mortality on rabbitbrush seedlings, young-mature plants, and old-mature plants. The data were not subjected to statistical analysis.

The most effective herbicide on each species was 2,4–D (Table 1). Grey rabbitbrush was as susceptible to 2,4–D as green rabbitbrush, but was apparently more resistant to the other materials used. In particular one may note that amitrol was ineffective on grey rabbitbrush but provided moderate control on green rabbitbrush. The comparison among age classes in terms of herbicidal effectiveness was inconclusive.

Test of additives with 2,4–D and 2,4,5–T on green rabbitbrush.

In 1954 and 1955, 2,4–D and 2,4,5–T (as propylene glycol butyl ether esters) were applied at acid equivalent rates of 0.5, 0.75, and 1.0 lb/A on 1/50-acre plots arranged in split-plot field design with three randomized blocks. A 2 x 3 factorial of herbicides and acid rates was assigned to whole plots, and eight levels of additive were assigned to sub-plots.

The eight levels of additive were as follows: (a) non-additive check, (b) urea at 5 lb/A of elemental nitrogen, (c) boric acid at 0.5 lb/A of

Table 1. Estimated mortality of green and grey rabbitbrush sprayed on June 5, 1954 with eight herbicides, each applied at an acid equivalent rate of 3 lb/A.

Herbicide	Percentage mortality by visual estimate			
	Seedlings	Young mature	Old mature	Average
Green rabbitbrush				
2,4-D butoxy ethanol	65	90	95	83
MCPA butoxy ethanol	70	70	50	63
Amitrol	40	65	70	58
2,4,5-T butoxy ethanol	35	50	50	45
silvex butoxy ethanol	40	50	20	37
3,4-DA iso-octyl	10	10	10	10
4-CPA butoxy ethanol	0	0	0	0
2,3,6-TBA sodium salt	0	0	0	0
Average	32	42	37	37
Grey rabbitbrush				
2,4-D butoxy ethanol	100	100	100	100
MCPA butoxy ethanol	35	50	25	37
2,4,5-T butoxy ethanol	20	30	0	17
silvex butoxy ethanol	5	20	5	10
3,4-DA iso-octyl	5	10	5	7
4-CPA butoxy ethanol	0	0	0	0
2,3,6-TBA sodium salt	0	0	0	0
Amitrol	0	0	0	0
Average	21	26	17	21

elemental boron, (d) Na_2Fe EDTA (disodium ferric ethylanediamine tetraacetate) at 0.5 lb/A of elemental iron, (e) Na_2Cu EDTA at 0.5 lb/A of elemental copper, (f) Na_2Zn EDTA at 0.5 lb/A of elemental zinc, (g) magnesium diacetyl acetone at 0.5 lb/A of elemental magnesium, and (h) maleic hydrazide at 1 lb/A of actual MH.

All materials were emulsified in water and applied at 6 gal/A with a back-pack sprayer. The three blocks of plots were sprayed on separate dates as follows: May 18, 1954, May 28, 1955, and June 7, 1955.

Green rabbitbrush mortality percentages were converted to angles for statistical analysis. Dates of spraying, herbicides, and additives were sources of significant variation in rabbitbrush mortality.

Among the additives, only zinc-containing solutions gave as much kill as the non-additive check solutions. Mean kills were 30 and 34 per cent respectively with non-additive and zinc-containing solutions. Three of the additives (boron, iron, and magnesium) gave mean kills of 2 per cent or less, which were significantly lower than that obtained with the non-additive, urea, copper, zinc, and MH solutions.

Mean kills by dates of spraying were 0, 47, and 20 per cent respectively on May 18, 1954, May 28, 1955, and June 7, 1955. The growing seasons in 1954 and 1955 were unusually short and dry, and periods for effective spraying were therefore short. Applications on May 18, 1954 and June 7, 1955 were near the termination of active rabbitbrush growth. The average mortality obtained by spraying on May 28, 1955 was fairly good considering the low acid rates used.

Average kills were 29 and 2 per cent respectively for 2,4–D and

2,4,5–T over all dates, acid rates, and additives but on May 28, 1955 mean kills with 1 lb/A were 85 and 70 per cent respectively for 2,4–D and 2,4,5–T.

Tests of spraying green rabbitbrush twice in one season.

In 1954 a jeep-mounted power sprayer was used to apply 2,4–D butyl ester (emulsified in water at 9 gal/A) on a mixed stand of green rabbitbrush and big sagebrush. The 100- by 100-foot plots were arranged in three randomized blocks of four plots each, to compare four treatments as follows: (a) untreated check, (b) a split application of 2 lb/A, in which 1 lb/A was applied on March 22 when green rabbitbrush leaf buds were beginning to swell and 1 lb/A on May 14 when associated sandberg bluegrass *(Poa secunda)* was flowering, (c) 1 lb/A on May 14, and (d) 2 lb/A on May 14.

Dead and living plants of green rabbitbrush and big sagebrush were counted on five 100-square-foot samples per plot in 1955 to determine mortality.

Mean kills of rabbitbrush were 0, 34, 72, and 85 per cent respectively for untreated check, 2 lb/A split application, 1 lb/A single application, and 2 lb/A single application. With treatments in the same order, sagebrush kills were 0, 100, 100, and 100 per cent respectively. In the split application, the initial treatment killed most of the leaf and terminal buds of rabbitbrush and induced vigorous lateral and basal sprouting. It was thought that this resprouting would cause the plants to be highly susceptible to 2,4–D applied later in the season; however, the split application of 2 lb/A was far less effective than a single application of either 1 or 2 lb/A when applied in an active stage of growth.

Tests of rate and time of application on green rabbitbrush.

In 1950, 10- by 50-foot plots were sprayed with a back-pack sprayer on nine dates (Table 2). The experiment constituted a 9 x 4 x 3 complete factorial with a single replication. (Three replications were involved in this experiment to determine mortality of big sagebrush, but stands of green rabbitbrush were sufficient for consideration on only a single replication. Big sagebrush mortalities resulting from those applications were reported by Hyder (3).) Since a single replication was involved in the consideration of rabbitbrush mortality, tests of significance in the analysis of variance were made by using interaction mean squares as estimates of error. Morality percentages were converted to angles for compilation and analysis.

The factorial experiment included four herbicides as follows: A 1:1 mix of 2,4–D and 2,4,5–T isopropyl esters in 20 per cent diesel oil emulsion, 2,4–D sodium salt in 20 per cent diesel oil emulsion, 2,4–D butyl ester in 20 per cent diesel oil emulsion, and 2,4–D butyl ester in water. Each herbicide was applied at acid equivalent rates of 1, 2, and 3 lb/A in a total solution volume of 10.9 gal/A. Notes on vegetative development and soil moisture levels were obtained throughout the spraying season.

Table 2. Mortality of green rabbitbrush and big sagebrush sprayed on nine dates in 1950 with 2,4-D butyl ester at 1, 2, and 3 lb/A.

Acid rates of 2,4-D in lb/A	Percentage mortality in 1950[a]									Average
	April 18	May 2	May 16	May 24	May 30	June 8	June 15	June 20	July 6	
Green rabbitbrush										
1	0	−7	−1	72	3	46	57	72	−28	10
2	−93	−19	38	57	66	94	59	52	19	20
3	12	1	41	69	89	90	92	89	−66	41
Average	−10	−4	17	66	50	80	71	72	−12	22
Big sagebrush										
1	54	71	64	74	65	71	61	40	5	56
2	71	82	79	86	82	86	82	52	23	71
3	80	94	87	90	87	96	91	67	25	80
Average	68	82	77	83	78	84	78	53	18	69

[a]Because of the small numbers of rabbitbrush, mortality percentages were transformed to angles for statistical analysis. Sagebrush mortality percentages were not transformed. The rabbitbrush mortality percentages given in this table are re-transformations from mean angles, consequently, "average" percentages are not arithmetic averages from the body of the table.

Herbicides, acid rates, and dates of spraying were sources of significant variation in rabbitbrush mortality. Rabbitbrush density increased 73 per cent on unsprayed check plots. Consequently, negative mortality values are real in the consideration of herbicidal effectiveness. The mean number of rabbitbrush before spraying was 12 plants per 500 square feet.

Mean kills were −9, 7, 22, and 23 per cent respectively for 2,4–D sodium salt, 1:1 mix 2,4–D and 2,4,5–T isopropyl esters, 2,4–D butyl ester in oil emulsion, and 2,4–D butyl ester in water. The 2,4–D sodium salt was significantly less effective than the 1:1 mix, and the 1:1 mix was significantly less effective than 2,4–D butyl ester. For simplification, the presentation of differences among acid rates and dates of spraying will be restricted to 2,4–D butyl ester.

Acid rates of 1, 2, and 3 lb/A of 2,4–D butyl ester gave mean kills of 10, 20, and 41 per cent respectively (Table 2). The 3 lb/A rate gave mean kills of 89, 90, 92, and 89 per cent respectively on May 30, June 8, June 15, and June 20. Acid rates of 1 and 2 lb/A did not give high kills consistently.

Time of spraying was obviously critical to herbicidal effectiveness. Green rabbitbrush had produced 3 to 4 inches of new twig growth by the first of June. Squirreltail *(Sitanion hystrix)* and Thurber needlegrass *(Stipa thurberiana)* were heading and sandberg bluegrass was in early flower when green rabbitbrush susceptibility reached maximum. The development of those grass species and others are summarized in Table 3. Seasonal soil moisture levels were reported by Hyder (3).

Tests of rate and time of spraying on mixed stands of green rabbitbrush and big sagebrush.

In 1955 applications were made on a mixed stand of green rabbit-

Table 3. Vegetative and reproductive development of grasses associated with green rabbitbrush and big sagebrush in 1950.

Species	Development criteria	April 24	May 8	May 15	May 23	May 29	June 5	June 14	June 19	July 5
Poa secunda	Leaves (inches)[a]	2.0	2.0	2.5	2.5	2.5	2.5	2.5		
	Stems (inches)[a]			4.0	5.5	7.0	7.0	8.0	9.0	
	Reproductive[b]		boot	heading		e.f.	f.f.	s.d.	h.s.	
	Herbage color[b]					l.c.	l.c.	l.c.	b.	b.
Sitanion hystrix	Leaves (inches)	5.0	4.0	4.5	5.0	6.0	5.0	5.0		
	Stems (inches)					6.5	6.0	8.0	8.0	8.0
	Reproductive				boot	heading		e.f.	f.f.	s.d.
Stipa thurberiana	Leaves (inches)	4.0	6.0	8.0	7.0	7.5	7.0	7.5		
	Stems (inches)					6.0	7.0	9.0	12.0	17.0
	Reproductive				boot	heading		e.f.	f.f.	h.s.
Koeleria cristata	Leaves (inches)	3.0	4.0	4.0	5.0	4.0	5.0	5.0		
	Stems (inches)						10.0	12.0	14.0	15.0
	Reproductive					boot	heading	e.f.	f.f.	l.f.
Agropyron spicatum	Leaves (inches)	4.5	6.5	6.5	7.5	9.0	9.0	10.0		
	Stems (inches)								15.5	20.0
	Reproductive						boot		heading	e.f.
Elymus cinereus	Leaves (inches)	5.0	7.0	8.5	10.0	11.5	12.5	16.0		
	Stems (inches)									26.0
	Reproductive								boot	heading

[a]Maximum leaf (stem) length was measured on ten or less of each species on each of 14 plots chosen at random, mean maximum leaf (stem) length is reported.
[b]Abbreviations are: e.f. = early flower, f.f. = full flower, l.f. = late flower, s.d. = soft dough, h.s. = hard seed, l.c. = loosing color, b. = brown.

brush and big sagebrush with a back-pack sprayer. This was a split-plot experiment in 3 replications with 7 dates of spraying on whole plots and a 4 x 2 factorial of herbicides and acid rates on sub-plots. Individual plots were 10 x 88 feet in size. The four herbicides applied were as follows: 2,4–D butyl ester, 2,4–D MPGE, 2,4,5–T PGBE, and silvex PGBE. These herbicides were applied at acid equivalent rates of 2 and 4 lb/A in water at 6 gal/A. Live plants were counted prior to spraying and again one year after spraying to determine mortality. Percentage-kill data for each species were subjected to statistical analysis. Notes on vegetative development were obtained on each date of spraying.

Herbicides, acid rates, and dates of spraying gave highly significant differences in green rabbitbrush mortality, but the interactions of these main effects were not significant.

Mean rabbitbrush kills were 16, 16, 8, and 3 per cent respectively for 2,4–D butyl ester, 2,4–D MPGE, 2,4,5–T PGBE, and silvex PGBE. The consideration of acid rates and dates of spraying will be restricted to the two 2,4–D materials, which were equal in effectiveness and significantly more effective than the other two herbicides.

Rabbitbrush mortality averaged 10 and 22 per cent respectively with 2,4–D at 2 and 4 lb/A (Table 4). Of greatest interest is the fact that kills did not reach 50 per cent at any time in 1955. This was an extremely dry year with moisture penetration into the soil not exceeding 10 inches. The two best dates for spraying were June 28, when green rabbitbrush was in full leaf but twig elongation was

Table 4. Mortality of green rabbitbrush and big sagebrush sprayed on seven dates in 1955 with 2,4-D esters at acid rates of 2 and 4 lb/A.

Acid rates of 2,4-D in lb/A	Percentage mortality in 1955							Average
	April 29	May 9	June 3	June 28	July 14	July 26	Aug. 10	
Green rabbitbrush								
2	2	−3	15	20	20	10	6	10[b]
4	−2	3	23	48	36	20	27	22
Average	0[a]	0	19	34	28	15	17	16
Big sagebrush								
2	70	97	94	12	4	1	2	40[b]
4	80	96	97	47	11	6	3	48
Average	75[a]	96	96	30	8	4	2	44

[a]LSD 5% level for comparing date means: 14 percent for rabbitbrush
6 percent for sagebrush

[b]LSD 5% level for comparing acid rate means: 5 percent for rabbitbrush
4 percent for sagebrush

slow, and July 14, when rabbitbrush flower buds were full and beginning to show some color. Mean maximum twig elongation was 3 inches on June 28 and 4.5 inches on July 14. Twig elongation was essentially complete by July 14. In a preceding section rabbitbrush kills from another site sprayed on May 28, 1955 were fairly good at the low acid rates applied. This suggests that better results might have been shown in the present experiment with closer timing of applications in late May and early June.

Soil moisture was depleted and sandberg bluegrass herbage was brown by the middle of June 1955. It has been reported that big sagebrush susceptibility to 2,4–D terminated with the depletion of soil moisture (3, 4). Tables 2 and 4 present the mortality of big sagebrush on the same plots from which green rabbitbrush mortality was obtained. Good sagebrush susceptibility to 2,4–D occurred 3 to 5 weeks prior to the occurrence of rabbitbrush susceptibility and appeared to drop more rapidly as soil moisture became limiting. Satisfactory kills of green rabbitbrush and big sagebrush in mixed stands were obtained in years with favorable moisture conditions, but not in the abnormally dry season of 1955.

Discussion and Conclusions

Green and grey rabbitbrush were more susceptible to ester forms of 2,4–D than to other herbicides used. Good rabbitbrush control was obtained with 2,4–D esters at an acid rate of 3 lb/A if treated at the proper time under favorable growth conditions. The 2,4–D was prepared in water or diesel oil emulsion at a total solution volume of 5 to 10.9 gal/A. Presumably, straight diesel oil also would be a suitable carrier.

With proper timing, big sagebrush and green rabbitbrush were controlled simultaneously. However, susceptibility in big sagebrush

developed earlier in the season and green rabbitbrush did not reach the susceptible stage of development in an abnormally dry year. Green rabbitbrush growing on some dry range sites might never be controlled satisfactorily. These facts present a hazard in the chemical control of big sagebrush, because selective killing of sagebrush in mixed stands of rabbitbrush and sagebrush would release the rabbitbrush for rapid increase, and create a more difficult brush problem.

It is suggested that in the chemical control of rabbitbrush favorable seasons must be chosen. A preliminary index in choosing favorable times for spraying is as follows: New twig growth on rabbitbrush must exceed 3 inches in length, sandberg bluegrass must have reached flowering development, squirreltail and Thurber needlegrass must be heading, and sandberg bluegrass herbage must retain some green color. With this timing, big sagebrush may also be killed satisfactorily.

SUMMARY

Green and grey rabbitbrush *(Chrysothamnus viscidiflorus* and *C. nauseosus)* were sprayed with various formulations of 2,4–D, 2,4,5–T, MCPA, 3,4–DA, 2,3,6–TBA, silvex, and amitrol at acid equivalent rates from 0.5 to 4.0 lb/A. Spraying was done in 1950, 1954, and 1955 with timing varying from late dormancy to early flowering of green rabbitbrush. Results from five separate experiments are reported.

Green and grey rabbitbrush were more susceptible to 2,4–D esters than to any of the other herbicides used. With 2,4–D esters, an acid equivalent rate of 3 lb/A gave good rabbitbrush control.

Proper timing for the control of green rabbitbrush requires the choice of favorable years as well as the susceptible stage of development. A preliminary index to rabbitbrush susceptibility is as follows: New rabbitbrush twig growth must exceed 3 inches in length, sandberg bluegrass *(Poa secunda)* must have reached flowering development, squirreltail *(Sitanion hystrix)* and Thurber needlegrass *(Stipa thurberiana)* must be heading, and sandberg bluegrass herbage must retain some green color. With this timing, big sagebrush *(Artemisia tridentata)* may also be killed satisfactorily.

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Re-establishment of Sagebrush Following Chemical Control[1]

L. W. Weldon, D. W. Bohmont, and H. P. Alley[2]

Increasing the forage yield of rangeland by controlling big sagebrush (*Artemisia tridentata* Nutt.) with fire, chemicals, or mechanical means has become a common procedure. The main problem confronting researchers has been the remarkable ability of sagebrush to re-establish itself after a control program. Fire and mechanical means of control have proved to be effective in killing established sagebrush. However, a heavy stand of young sagebrush often becomes re-established within a few years (3). Since the use of chemicals for sagebrush control has developed within the last decade, very little is known concerning the re-establishment of the plant in chemically controlled areas.

Hyder (6) found, upon spraying three different sagebrush stands, 2 old-mature stands and a young-mature stand, that the average mortality was 8 per cent greater for the old-mature stands than for the young-mature stand. He recommended (7) 1 pound of butyl ester of 2,4–dichlorophenoxy acetic acid (2,4–D) per acre for old-mature stands. Where sagebrush seedlings are prevalent in the understory or the stand is young-mature, 1.5 pounds per acre should be applied. Such an application will result in 70 to 80 per cent kill, with the crowns of the remaining plants partially killed. From these studies one would assume that young sagebrush is more tolerant to 2,4–D than old-mature sagebrush plants.

Hyder's results did not agree with those of Hull and Vaughn (5), who found that sagebrush plants reacted much the same regardless of age class. There was a tendency for smaller plants to be either completely dead or completely alive, while the large old plants would have some dead and some live stems. The percentages of plants killed were found to be similar for both young and old sagebrush plants. Alley (2), however, was in accordance with Hyder, as he noted that the young sagebrush has a tendency to be more tolerant to selective herbicides than do old sagebrush plants. He also noted that parts of sagebrush clumps remained alive even after complete coverage by chemical spray. Studies made by Kissinger, Hull, and Vaughn (4) in central Wyoming also showed that sagebrush seedlings were less susceptible to both 2,4–D and 2,4,5–trichlorophenoxyacetic acid (2,4,5–T) than were older plants. Robertson and Cords (8) sprayed sagebrush of three age classes at different times in the summer. The three classes were: A, old, mature shrubs up to 4 feet tall and others down to 4 inches tall; B, suppressed

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[2]Formerly Graduate Research Assistant, Univ. of Wyoming, now Research Agronomist, Crops Protection Research Branch, USDA, Univ. of Wyoming; Head, Dept. of Agronomy; and Research Assistant, Dept. of Agronomy, University of Wyoming, Laramie, respectively.

juveniles and seedlings less than 4 inches tall under the mature stand; and C, shrubs 4–15 inches tall that had sprung up in the crested wheatgrass during the preceding 10 years. Class A proved to be the most resistant age to 2,4–D applications. All classes were most susceptible in May, normally the most active growing period of sagebrush. While these studies vary in their results concerning tolerance of young sagebrush to 2,4–D or 2,4,5–T, none of the experimenters had studied re-establishment of sagebrush after a control program.

The purpose of this experiment was twofold: (1) To determine the degree of reinvasion of sagebrush into sprayed rangeland 3 years after initial control, and (2) to determine the effect of age upon susceptibility of the sagebrush to 2,4–D treatments.

METHODS

The experimental area, located in the Big Horn mountains of northern Wyoming, has an average annual precipitation of 20 inches at an elevation of 8,200 feet. Typical sagebrush rangeland was selected, one area grazed by cattle and the other by cattle and sheep, both being sprayed with various concentrations of 2,4–D and 2,4,5–T and with combinations of the two chemicals in June 1952. An area containing approximately 310 acres was subdivided into 7.5-acre sprayed plots and 3.5-acre isolation strips between the plots. One half of each plot was retreated in 1953. The amount of sagebrush control varied from 0 to 100 per cent as a result of the various chemical treatments. The original treatments and control were reported in an earlier study (1). This offered an excellent opportunity to study the effect of different degrees of sagebrush control upon the re-establishment of sagebrush.

Sagebrush seedling study.

Each plot was surveyed with 50 random placements of a 2-square foot quadrat. The young sagebrush plants in the quadrat were recorded and grouped according to age. Age was determined by ring counts of several hundred sagebrush plants whereby growth characteristics and number of growth rings were correlated to allow determination of age without actually cutting every plant. The six age groups were: (1) 1 year old, (2) 2 and 3 years old, (3) 4 to 6 years old, (4) 7 to 9 years old, (5) 10 to 12 years old, and (6) plants 13 to 20 years old. Plants over 20 years old were mature and producing seed while all plants under 20 years old in the study area did not produce seed. No distinction was made between old-mature and young-mature as any plant under 20 years old not producing seed was considered to be immature. Other studies (6) defined young-mature sagebrush as 30 years of age and old-mature sagebrush as 60 years. Differences in young sagebrush populations were analyzed statistically according to percentage of sagebrush control. Data were summarized on the basis of 0, 50 to 75, 76 to 90, and 91 to 100 per cent sagebrush control. The data were also summarized according to chemical treatments.

2,4–D toxicity study.

Young sagebrush plants of various ages were transplanted into clay pots the first of August and placed in the greenhouse. Sagebrush seed was planted to obtain seedlings. The plants collected in the field were classified as to 1 to 3, 4 to 6, and 7 years old. Individuals of all four age classes were then treated with 1/4, 1, and 2 pounds per acre of the propylene glycol butyl ether ester of 2,4–D acid with a constant-speed and pressure greenhouse sprayer. The chemical was applied in water at a calibrated rate of 9.5 gallons per acre. All pots of each treatment were maintained under greenhouse conditions for the duration of the study. The toxicity of the different chemical treatments upon the various age groups was observed during the 4 months following chemical application.

RESULTS AND DISCUSSION

An extensive survey made in 1955 of the chemically controlled big sagebrush plots gave indications that areas of 75 per cent or more initial control have fewer young sagebrush plants than areas of lesser initial control. Significantly fewer young sagebrush plants were found in areas of 91 to 100 per cent initial control than in areas of less than 75 per cent control. The areas of 76 to 90 per cent initial sagebrush control had fewer young plants than areas with 91 to 100 per cent control, when compared at the 5 per cent level of probability (Table 1).

Table 1. Average numbers of sagebrush plants in six age groups, found in four areas of initial control. Each figure represents an average of four plots, each of which was sampled by 50 random placements of a 2-square foot quadrat.

Age groups	Percent initial sagebrush controlled				
	0	50–75	76–90	91–100	Av.
1 year	39	40	34	11	31.1
2 to 3	42	39	14	14	27.6
4 to 6	40	41	23	7	28.2
7 to 9	13	4	3	1	5.5
10 to 12	4	1	1	0	2.1
20 to 20	3	2	0	0	1.0
Average	24.0	21.4	12.9	5.9	
Age LSD 5%	33.3	38.1	21.7	4.4	11.6
1%			30.0	6.1	15.4
Control LSD 5%					9.4
1%					12.6
Control x age LSD 5%					23.1
1%					30.8

The young sagebrush plants were classified into six age groups: 1, 2 to 3, 4 to 6, 7 to 9, 10 to 12, and 13 to 20 years old. Statistical analysis showed sagebrush plants of the first 3 age groups to be more abundant than sagebrush plants 7 years or older (Table 1). When each area of control was statistically analyzed, the same breaking point between 6 and 7 years was observed.

The areas of 91 to 100 per cent control were found to have significantly fewer seedlings 4 years or older. Since the plots were sprayed in 1952, it is reasonable to assume that the more effective chemical treatments reduced the stands of young sagebrush. Young sagebrush plants 1, 2, and 3 years old were found in dense stands near mature seed-producing sagebrush plants (Figures 1 and 2).

Figure 1. A thick stand of young sagebrush becoming established under a mature seed-producing plant.

Summarization of the data according to chemical treatments showed no differences between chemicals as long as the degree of control was the same. Therefore, percentage control was the most important factor in re-establishment of sagebrush. There were no differences found in numbers of young or seedling sagebrush between areas grazed by cattle alone or with both cattle and sheep.

2,4–D toxicity study.

Sagebrush plants of four age groups were sprayed with ¼, 1, and 2 pounds of 2,4–D acid per acre. All seedlings were found to be completely susceptible to applications of 1 or 2 pounds of 2,4–D per acre. Within 2 weeks the seedlings had visible 2,4–D symptoms, while plants over 7 years old did not show symptoms of 2,4–D damage until 3 months after application. Another month was required before most of the leaves had fallen (Figure 3).

The ¼-pound rate of 2,4–D was found to be ineffective for controlling any age group of sagebrush plants studied. The seedlings

Figure 2. A dense stand of 1- to 3-year-old sagebrush plants found growing in relatively bare areas near mature plants.

were found to be the most susceptible age group, as they were easily killed by 1 pound of 2,4–D.

Sagebrush plants 4 years old and older were found to be more resistant to 2,4–D than younger plants. A single treatment of 2 pounds of 2,4–D per acre applied to mature sagebrush stands 35 to 60 years old may be expected to kill 70 to 90 per cent of the stand, which is essentially the same results as when 2 pounds of 2,4–D was applied to the young plants under controlled environmental conditions. The 2-pound rate gave double the kill of sagebrush obtained with a 1-pound application.

CONCLUSIONS

1. A reduction in young sagebrush plants was noted when initial sagebrush control exceeded 75 per cent.

2. Large numbers of young sagebrush up to 4 years of age were found in all plots, but relatively few sagebrush plants 4 years and older were present in the chemically treated plots.

3. Sagebrush seedlings under greenhouse conditions were found to be more susceptible than older plants to 2,4–D applications.

4. A single application of 2 pounds of 2,4–D gave 76 per cent control of young sagebrush under controlled environmental conditions.

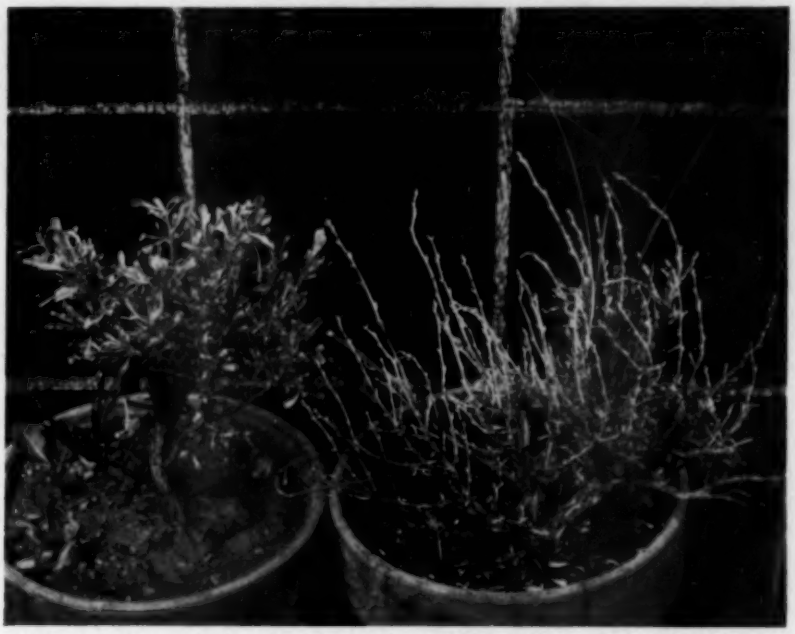

Figure 3. Two sagebrush plants over 7 years old. The plant on the right was treated with 2,4–D 2 lb/A while the plant on the left was not treated.

5. Rangeland on which 75 per cent or more of the sagebrush has been chemically controlled may be expected to remain relatively free from sagebrush seedlings for at least a 4-year period after chemical treatments.

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Comparative Costs of Weeding Onions by Hand or with Monuron, CIPC, and CDAA[1]

R. E. Nylund, D. C. Nelson, and D. H. Dinkel[2]

Weed control constitutes one of the principal costs of onion production on muck soils. It has been estimated that cultivating and weeding make up nearly 40 per cent of the total labor cost in growing onions (5). The major component of this weed control cost is the hand labor required to remove weeds which come up in the onion row. During the past several years, research to find selective weedicides for onions and thus reduce weeding labor costs has been extensive.

Several herbicides have been effective in controlling weeds in seeded onions on muck soils. Among these are 3–(*p*–chlorophenyl)–1,1–dimethylurea (monuron), isopropyl N–(3–chlorophenyl)carbamate (CIPC), and 2–chloro–N,N–diallylacetamide (CDAA). Monuron has been tested widely both as a pre-emergence herbicide (3, 6, 8, 10, 15) and for post-emergence use (1, 3, 4, 7, 10, 15, 16). CIPC has also been tested by many investigators (1, 3, 4, 5, 8, 15, 16) and is widely used by growers. Combinations of monuron and CIPC have sometimes given more effective weed control than either herbicide alone (3, 9, 11). More recently, CDAA has shown considerable promise for use in onions (12, 13, 14).

Few studies have been conducted to determine onion hand-weeding costs and the savings, if any, which might be effected by the use of these herbicides. Alban (2) showed that in a commercial field of onions, the application of 6 lb/A of CIPC as a pre-emergence spray followed by three 4-pound post-emergence applications of the same herbicide reduced hand-weeding costs from $75 per acre to $45 per acre. In smaller plots at the Ohio Agricultural Experiment Station he showed that a pre-emergence application of 6 pounds CIPC followed by a single post-emergence application of 6 pounds CIPC reduced hand-weeding cost from $129 per acre to $75 per acre (2). In a preliminary study (11) on the effects of herbicides on onion weeding costs, Nylund found that the application of either 1.6 pounds monuron or 8 pounds CIPC per acre as pre-emergence sprays or at the onion one-leaf stage reduced hand-weeding labor costs by approximately 44 per cent. Application of either monuron or CIPC at the onion three-leaf stage did not reduce the labor requirement for the second hand-weeding.

The present paper is a report of experiments conducted in 1956 and 1957 to determine onion hand-weeding costs and the savings which might be effected by the use of monuron, CIPC, or CDAA.

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[1]Paper No. 3828, Scientific Journal Series, Minnesota Agricultural Experiment Station.

[2]Associate Professor, Research Fellow, and Research Assistant, respectively, Department of Horticulture, University of Minnesota, St. Paul 1.

MATERIALS AND METHODS

In both 1956 and 1957 Brigham Yellow Globe onions were seeded in muck soil as early as practicable, on April 19 in 1956 and on April 29 in 1957. Herbicide treatments were applied to plots 6 feet wide (4 rows) x 18 feet long. Each treatment was replicated five times. Sprays were applied at 35 psi pressure in 80 gal/A water. To obtain data on hand-weeding labor costs, all hand-weedings were timed with a stopwatch. Data on hand-weeding time and yields of onions were recorded for the center two rows of each plot. Hand-weeding labor costs were calculated at $0.75 per hour and spraying costs at $1.00 per acre per application. Costs of mechanical cultivation, which was the same for all plots, were not calculated.

The herbicide treatments applied were somewhat different in each of the two years. In 1956, monuron at 1.6 pounds per acre, CIPC at 8 pounds, and a mixture containing 0.8 pound monuron and 4 pounds CIPC were applied three times to duplicate sets of plots in each replication. One set was hand-weeded in the row when necessary and the other was left unweeded in the row. Hand-weeded and unweeded checks were also included. All plots were machine-cultivated when necessary to control weeds between the rows. The three dates of herbicide application in 1956 were May 8, May 29, and June 26. On the first date, neither onions nor weeds had emerged. On May 29, onions were at the one-leaf stage, purslane *(Portulaca oleracea)* was in the 2 to 4 leaf stage, and barnyard grass *(Echinochloa crusgalli)* was in the 2 to 3 leaf stage. On June 26, onions were at the 4 to 5 leaf stage, and the two species of weeds were at various stages from just emerging to large plants. Herbicides applied on May 8 and May 29 were applied over the onion rows, but those on June 26 were applied as directed basal sprays.

In 1957, monuron at 1.6 pounds, CIPC at 8 pounds, and CDAA at 4 pounds per acre were applied pre-emergence (May 8) to two sets of plots and at lay-by (July 19) to one of the two sets previously sprayed. On May 8, numerous weeds in the cotyledon stage were present. These included smartweed *(Polygonum pensylvanicum)*, shepherd's purse *(Capsella bursa-pastoris)*, lambsquarters *(Chenopodium album)*, pigweed *(Amaranthus retroflexus)*, purslane *(Portulaca oleracea)*, foxtails *(Setaria spp.)*, and barnyard grass *(Echinochloa crusgalli)*. On July 19, purslane in mats 6 to 10 inches in diameter and smartweed up to 12 inches tall were present. The July 19 herbicide applications were directed basal sprays.

RESULTS

1956 trial.

Table 1 shows the treatments applied in 1956 and weeding time required per acre at each weeding. The pre-emergence application of herbicides plus, possibly, the first post-emergence application eliminated the first hand-weeding. Whether or not the second and third applications of herbicides were effective in reducing later

Table 1. Hours labor required to hand-weed onions given various weed control treatments, 1956.

Herbicide per application	Dates of application	Labor to hand weed—hrs/A			
		6/4	6/18	8/1	Total
Handweeded	———	43	78	49	170
Monuron 1.6 lb/A	5/8,5/29,6/26	0	39	12	51
CIPC 8 lb/A	5/8,5/29,6/26	0	84	23	107
Monuron 0.8 lb/A + CIPC 4 lb/A	5/8,5/29,6/26	0	68	11	79
LSD 5% level					84
LSD 1% level					117

hand-weeding labor requirements is difficult to determine from this trial. The lower labor requirement for weedings on June 18 and August 1 may be due, at least partially, to residual effects of the pre-emergence herbicide application. For the entire season monuron applications reduced hand-weeding labor from 170 hours per acre to 51 hours per acre, or 70 per cent. CIPC reduced hand-weeding labor 37 per cent and the monuron–CIPC combination reduced hand-weeding labor 54 per cent.

Table 2 gives the onion yields and weeding costs per acre under all treatments. No marketable onions were obtained from the unweeded checks but the unweeded sprayed plots, which did not differ significantly in yield, produced approximately 40 per cent that of the yield of the hand-weeded controls. In terms of the hand-weeded control plots, the hand-weeded sprayed plots produced as follows: Monuron 81 per cent, CIPC 97 per cent, and monuron plus

Table 2. Weeding costs per acre and onion yields under various methods of weed control, 1956.

Weed control treatments	Labor to hand-weed hours	Weeding costs per acre—dollars			Onion yields bu/A
		Hand-weeding labor cost	Approximate herb. cost	Total	
Unweeded					
No herbicide	—	0	0	0	0
Monuron	—	0	25	25	384
CIPC	—	0	45	45	440
Monuron and CIPC	—	0	35	35	348
Handweeded					
No herbicide	170	127	0	127	978
Monuron	51	38	25	63	793
CIPC	107	80	45	125	950
Monuron and CIPC	79	59	35	94	804

CIPC 82 per cent. Statistically, none of these yields were significantly below that of the unsprayed hand-weeded control. The most effective herbicide treatment, monuron, reduced hand-weeding costs from $127 per acre to $63 per acre or approximately 50 per cent. CIPC was somewhat less effective in this study and, while it reduced labor requirements 37 per cent, its high price prevented any saving

in total hand-weeding costs. The combination of monuron and CIPC reduced hand-weeding costs 26 per cent.

1957 trial.

All plots were hand-weeded four times in the 1957 trial. The labor time required for each of these weedings is given in Table 3. All pre-emergence herbicide treatments gave significant residual weed control for at least 7 weeks. Monuron apparently gave residual weed control for another 3 weeks but CIPC and CDAA did not. The final weeding (July 22) was made too soon after the lay-by treatment to give much indication of the herbicidal value of this treatment. All of the treatments reduced total weeding time by approximately 50 per cent.

Table 3. Hours labor required to hand-weed onions given various weed control treatments, 1957.

Herbicide per application	Dates of application	Labor to hand-weed—hrs/A				
		5/31	6/12	6/28	7/22	Total
Handweeded	——	33	28	18	32	111
Monuron 1.6 lb/A	5/8	14	12	8	22	56
Monuron 1.6 lb/A	5/8,7/19	13	9	9	20	51
CIPC 8 lb/A	5/8	13	9	6	32	60
CIPC 8 lb/A	5/8,7/19	13	7	5	24	49
CDAA 4 lb/A	5/8	11	10	9	29	59
CDAA 4 lb/A	5/8,7/19	11	10	7	25	53
LSD 5% level		5	6	3	8	16
LSD 1% level		7	8	4	11	21

The weeding data converted to labor costs are given in Table 4, together with total weeding costs and onion yields. Single pre-emergence applications of either monuron, CIPC, or CDAA reduced hand-weeding labor costs 34 to 40 per cent. The additional lay-by application, in this study, did not reduce costs further. None of the herbicide treatments affected onion yields, which were very low in 1957 due to excess rainfall during July and August.

Table 4. Weeding costs per acre and onion yields under various methods of weed control, 1957.

Herbicide per application	Dates of application	Labor to hand-weed hours	Weeding costs per acre—dollars			Onion yields bu/A
			Hand-weeding labor cost	Approximate herb. cost	Total	
Handweeded	——	111	83	0	83	237
Monuron 1.6 lb/A	5/8	56	42	8	50	239
Monuron 1.6 lb/A	5/8,7/19	51	38	17	55	217
CIPC 8 lb/A	5/8	60	45	15	60	215
CIPC 8 lb/A	5/8,7/19	49	37	30	67	198
CDAA 4 lb/A	5/8	59	44	11	55	199
CDAA 4 lb/A	5/8,7/19	53	40	22	62	222
LSD 5% level		16				n.s.

SUMMARY

1. Studies were conducted in 1956 and 1957 to determine hand-weeding costs for onions grown on muck land and to determine the effects of chemical weeding on these costs.

2. Labor required to hand-weed onions was 170 hours per acre in 1956 and 111 hours in 1957. At prevailing wage rates, the weeding cost, exclusive of cultivation costs, were $127 and $83 per acre for 1956 and 1957, respectively.

3. In 1956, monuron applied three times at 1.6 pounds per acre reduced weeding time 70 per cent and weeding costs 50 per cent.

4. Three applications of CIPC at 8 pounds per acre reduced weeding time 37 per cent, but did not reduce weeding costs.

5. Three applications of a mixture of 0.8 pound monuron and 4 pounds CIPC reduced weeding time 54 per cent and weeding costs 26 per cent.

6. In 1957, single (pre-emergence) and double (pre-emergence and lay-by) applications of 1.6 pounds monuron, 8 pounds CIPC, or 4 pounds CDAA reduced total weeding time by approximately 50 per cent. A single application of herbicides reduced weeding costs 34 to 40 per cent, but a second application did not reduce weeding costs further.

7. Three applications of monuron alone or in combination with CIPC tended to reduce onion yields in 1956, but CIPC alone had no effect on yields. In 1957, two applications of monuron, CIPC, or CDAA had no effect on yields, which were generally low due to excess rainfall during July and August.

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A Study of Some Bioassay Methods for Herbicide Volatility

J. K. Leasure[1]

The problem of herbicide volatility has been with us for several years, and promises to remain with us for some time. Mullison, et al. (4) in 1953 pointed out the reasons why physical measurements of herbicide volatility were impractical. Their arguments that the phenoxy herbicides generally have a low order of physical volatility and that analytical methods are insufficiently sensitive to measure the amounts of such herbicides which escape through volatility are still valid.

At the present time biological methods of measuring the relative volatility of 2,4–dichlorophenoxyacetic acid (2,4–D) formulations (and formulations of similar materials) are in wide use. There is, however, no standard test method which is acceptable to all investigators who are concerned with herbicide volatility.

To be widely accepted, any method must be easy to operate with readily available equipment. It must give results which are easily duplicated in various laboratories; and it must give results which are indicative of the performance of the material in the field.

Perhaps the methods being used most widely are the method described by Zimmerman and Hitchcock (7), the air-flow method of Baskin and Walker (2) and the cucumber root-tip determination described by Ready and Grant (6). Modifications of all of these are currently in use in federal and state research laboratories, in federal and state regulatory laboratories, and in industrial laboratories.

Two of these methods, those proposed by Mullison and Hummer (5) and by Ready and Grant (6), were developed by using as pure samples of 2,4–D acid and 2,4–D esters as could be readily obtained. The reports did not contain results with proprietary formulations. Nevertheless, all three methods have been used to determine the relative volatility of commercial formulations of 2,4–D and 2,4,5–trichlorophenoxyacetic acid (2,4,5–T).

It has been rather widely assumed that for esters of 2,4–D and related materials, the oils, wetting agents, and emulsifiers added in formulating the product have little or no effect on the volatility of the product. While this appears to be true when field applications are considered, it is not necessarily true for all of the bioassay methods which are currently in use. Actually, some effects of formulation additives on the volatility of herbicides have been previously reported. Marth and Mitchell (3) reported that the butyl ester of 2,4–D was not volatile when dissolved in diesel oil, corn oil, or cottonseed oil, but that formulating it in Varsol, kerosene, or castor oil did not appreciably reduce its volatility.

[1]Agricultural Chemicals Research, The Dow Chemical Co., Midland, Michigan.

EXPERIMENTAL METHODS AND RESULTS

Samples of the n–butyl ester of 2,4–D, the isopropyl ester of 2,4–D, the technical propylene glycol butyl ether ester of 2,4–D (PGBE ester of 2,4–D), various lots of commercially formulated PGBE ester of 2,4–D (Esteron Ten-Ten), and the emulsifier, the wetting agent and the oil which make up the commercial formulation were tested for volatility using all three methods previously mentioned. In a modification of the method of Zimmerman and Hitchcock (7), one milliliter of each material was pipetted onto filter paper in a 60 mm petri dish. Each dish was placed on a glass plate adjacent to two Bonny Best tomato plants 4 to 6 inches tall, and the plants and petri dishes were covered with bell jars. The bell jars were then held in a constant temperature cabinet for 48 hours at 90° F.

After exposure, the plants were examined, the number of leaves reflexed were counted, stem effects were noted, and the plants were assigned a numerical rating from the scale proposed by Baskin and Walker (1) wherein 1 = no apparent response, 2 = epinasty 1–20° compared to normal, no curling, 3 = epinasty 21–40° compared to normal, slight curling, 4 = epinasty 41–60° compared to normal, moderate curling, 5 = epinasty 61–80° compared to normal, moderately severe curling, and 6 = epinasty 81° to greater than 90°, severe formative effects apparent (twisting of main stem, distortion of petioles and leaflets).

In using the method described by Mullison and Hummer (5), samples of dry cucumber (variety Straight Eight) and mustard (variety Southern Giant) seed were suspended in jars above a filter paper on which one milliliter of each of the test chemicals had been pipetted. The jars were then sealed for 14 days, after which germination tests were run in duplicate on each lot.

In using the method of Ready and Grant (6), cucumber seeds were placed on moist filter paper in 60 mm petri dishes, which were then placed in glass jars containing water absorbed on paper towels to maintain a high humidity for seed germination and seedling development. One milliliter of each test chemical was placed on filter paper in separate petri dishes which were then placed in the jars. The jars were then sealed, and held in a constant temperature cabinet in the dark for 4 days at 90° F. After the exposure period, the petri dishes were removed, and the primary root and hypocotyl lengths were measured in millimeters.

Table 1 summarizes the results of the three tests and illustrates the discrepancies in the results obtained by using the different methods.

The results of the bell jar test show that the butyl and isopropyl esters of 2,4–D produced pronounced growth regulator effects on the test plants, but that tomato plants exposed to the isooctyl ester, or to the PGBE ester, formulations of the PGBE ester or components of the formulation did not differ markedly from untreated plants.

In the dry seed test, the isopropyl ester and butyl esters of 2,4–D caused significant reductions in the germination of both species,

Table 1. The results of volatility tests by three different methods.

Test material	Bell jar test USDA rating scale	Dry seed test percent germination		Cucumber root test	
		Mustard	Cucumber	Mean root length in mm	Mean hypocotyl length in mm
n-Butyl ester of 2,4-D	6	29	6	4.7	6.4
Isopropyl ester of 2,4-D	6	17	0	3 to 5 mm	total*
Isooctyl ester of 2,4-D	2	87	93	14.1	45.6
PGBE ester of 2,4-D	2	86	94	23.0	61.6
Commercially formulated PGBE ester of 2,4-D					
Lot 1	2	88	99	10.7	24.0
Lot 2	2	86	92	16.9	23.8
Wetting agent	1	90	96	44.1	70.8
Emulsifier	1	85	97	47.4	74.8
Penola heavy aromatic naphtha	1	88	93	3 to 5 mm	total*
Control plants	1	87	98	46.2	74.2

*Root and hypocotyl were indistinguishable at this stage.

but none of the other materials tested had any effect on either species.

The data from the cucumber root test show clearly that vapors from the commercial formulation cause a much greater reduction in the growth of both the primary root and hypocotyl length of cucumber seedlings than does the PGBE ester (tech.) which is its active ingredient. Further, the vapors from the oil used in the formulation cause almost complete inhibition of cucumber seedling development under the conditions of this test. These results indicate that some formulation additives can affect measurements of relative volatility of herbicide formulations under certain conditions. The data also indicate that the addition of the PGBE ester (tech.) to the oil probably reduces the effect of the oil somewhat.

In order to determine the conditions under which formulation additives can affect the results of the bioassay measurement of herbicide volatility, further experiments were run with different formulation additives.

A group of 40 common and commercially available solvents (including a number which are regularly used in various herbicide formulations) were tested using all three bioassay methods. The results confirmed those reported above. None of the solvents showed any effect except in the cucumber root tip assay. Here, effects varied from slight to very severe, with 24 of the solvents causing a greater reduction in cucumber root length than did the commercial formulation of PGBE ester of 2,4–D.

Since it was now obvious that there were effects from several solvents, formulations of 2,4–D were made up in the laboratory using various solvents. A standard Esteron Ten-Ten type formulation (except for the oil) was prepared; and the various solvents were added to subsamples, resulting in a group of formulations varying only in the oil component. These formulations were also tested by all three bioassay methods.

This group of formulations gave essentially uniform results when tested by the methods of Mullison and Hummer (5) and of Zimmer-

man and Hitchcock (7). They gave quite varied results by the method of Ready and Grant (6).

Although there was a range of root lengths from 41.6 mm to zero and of hypocotyl lengths from 70.7 mm to zero, there were clearly three response groups. These groups were evident in a visual examination of the results, and a statistical analysis of the root and hypocotyl lengths confirmed that the groups were significantly different. One group (5 formulations), not significantly different from the check, had root lengths from 25 to 40 mm and hypocotyl lengths from 55 to 70 mm. Another group of 22 formulations showing marked effects, had root lengths from 15 to 25 mm and hypocotyl lengths from 18 to 46 mm, while in a third group (13 formulations), development was severely suppressed, having total growth of less than 8 mm, with root and hypocotyl being indistinguishable.

Although a majority of the aromatic solvents severely suppressed cucumber growth in this test, while the aliphatic solvents generally had a lesser effect, there were some exceptions to this. Some of the aliphatic hydrocarbons caused as severe suppression of growth as any of the aromatics. The exact reasons for all of the various group responses are not clear at the present time.

DISCUSSION

The three bioassay methods described do not give concurring results when all three are used to measure the relative volatility of 2,4–D formulations. The data clearly demonstrate that a major part of the discrepancy results from the effect of the vapors of various solvents on germinating cucumber seedlings.

It appears that either the method of Zimmerman and Hitchcock (7) or the method of Mullison and Hummer (5) would be entirely satisfactory for the determination of the relative volatility of halophenoxy–aliphatic acid herbicides. Either method can be modified in a number of ways to fit the conditions existing in various laboratories, and still give comparable results. Modifications of the Zimmerman and Hitchcock method are widely used at the present time with satisfactory results. Since this method requires a supply of uniform plants, state control laboratories may find it difficult to adapt this method for their use. Such laboratories generally are well equipped for seed germination tests. For their purposes, a modification of the Mullison and Hummer method should prove to be satisfactory.

Since the modification of the method of Ready and Grant (6) does not give uniform results with different formulations of the same lot of technical ester of 2,4–D, it would seem that it is an unreliable test of the volatility of different commercial formulations of esters of 2,4–D or 2,4,5–T. Although the authors specifically state that this method was developed "for the assay of 2,4–D acid in aqueous solutions", this method can be modified to give results which are satisfactory for comparing the relative volatility of samples of technical esters of 2,4–D and similar materials. Tests made with various unformulated lots of technical ester showed that comparable results

can be obtained so long as the results are not confounded by the effects of some of the ingredients of the formulation other than the ester. The results indicate that this modified method would be completely unsatisfactory for federal or state regulatory laboratories, since their samples are taken from formulations offered for sale, and the ingredients other than the active ingredients are not ordinarily stated on the label.

SUMMARY

Three of the methods for determining the relative volatility of herbicides which are currently being used in several laboratories were evaluated by testing almost a hundred different solvents and formulations by all three methods. It was found that formulation additives can affect the results obtained with at least one method. Methods suitable for use by control laboratories are recommended.

It is considered that the findings of this work are applicable primarily to laboratory determinations, and have no particular bearing on the results which might be expected from field applications. The extreme sensitivity of the cucumber-root bioassay method to solvents as well as to phenoxy-type herbicides precludes the application of results from this test to predictions of the field behavior of herbicides.

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Interactions of Maleic Hydrazide and Endothal[1]

MOACYR MAESTRI[2] and H. B. CURRIER[3]

INTERACTIONS among the components of an herbicidal solution may take place (a) in the solution itself, (b) at the plant surface or within tissues to influence absorption and translocation, and (c) at the cellular site of toxic action. This broad meaning of the term interaction is employed in the present report. Similarly, the meanings of antagonism and synergism are considered as inhibition and enhancement, respectively, of the toxic action of one substance due to the influence of another, regardless of the location and nature of the interaction.

Crafts, Currier, and Drever (1) recently made some observations which indicate a possible antagonism between endothal [disodium salt of 7–oxabicyclo (2.2.1) heptane–2,3–dicarboxylic acid] and MH (maleic hydrazide, or 1,2–dihydro–3,6–pyridazinedione) on bermudagrass. Previously, Pridham and Hsu (14) showed that combinations of MH or naphthaleneacetic acid with endothal sprayed on *Ligustrum ovalifolium* retarded defoliation. The same retardation of defoliation was observed when these dormancy-inducing growth-regulators were applied sometime before the endothal spray. For *Forsythia intermedia spectabilis*, MH sprayed 1 week or more in advance of endothal neither interfered with the defoliant action of endothal nor consistently retarded bud break (13). An increase in defoliation of cotton by a mixture of endothal and MH was observed by Hall and Lane (6), although they state that an excessively high concentration of endothal (2%) was used, explaining the poor defoliation obtained with endothal alone.

In view of these reports, it was considered worthwhile to undertake some studies on possible interactions of endothal and MH. Endothal is a chemical highly toxic to plants. It has been used as a defoliant, as a desiccant, and as a pre-emergence and contact herbicide (11, 18). Maleic hydrazide has elicited many publications since its first description as a growth inhibitor (15) and its indication as a potential herbicide (3). Literature summaries of MH studies up to 1957 are available.[4]

MATERIALS AND METHODS

Barley (variety Atlas) and bermudagrass served as test plants. The diethanolamine salt of MH (MH–30), containing 30% MH by weight, and technical grade (90%) endothal were used. In the translocation tests C^{14}-MH (labeled in one of the ethylene carbons) and C^{14}-amitrol (labeled in carbon 5) were employed as foliar-applied tracers.

[1]This paper is adapted primarily from an M.S. thesis presented by the senior author to the Graduate Division, University of California, 1957.

[2]Present address: Escola Superior de Agricultura, Viçosa, Minas Gerais, Brasil.

[3]Associate Professor of Botany, University of California, Davis.

[4]Naugatuck Chemical Division, Naugatuck, Conn.

The present studies consisted of greenhouse experiments, translocation tests with labeled chemicals, and respiration experiments. Procedures will be described accordingly under three sub-headings.

Greenhouse experiments. Barley plants were grown in No. 2 cans containing a fertile loam soil. When the third leaf became visible, about 12 days after seeding, the plants were sprayed to runoff with MH and endothal. These chemicals were applied singly, in various combinations, and in varying sequence (see Table 1). Vatsol OT at 0.05% was present in all solutions. Contamination of the soil was avoided. Two to 4 weeks after spraying, depending upon the experiment, the fresh weights of the tops were determined.

Established sod cultures of bermudagrass in gallon cans were sprayed to runoff with MH and endothal, singly and in various combinations. Soil contamination was avoided as before. After 40 days, the fresh weights of shoots were recorded.

In another procedure barley was cultured in quart Mason jars containing Hoagland's nutrient solution. The toxicants, MH and endothal, were added to the solution and roots so treated for 8 hours. The plants were then transferred to plain Hoagland's solution. Fresh weights of shoots were measured 12 days later.

Four replicates (cans or jars) were employed in the above experiments. In the soil tests barley was thinned to 7 plants per can; in the solution culture there were 10 plants per jar. For the solution culture and bermudagrass tests a randomized block design was used.

Translocation studies. Radioautographic techniques developed in the Botany Department at Davis were followed in the translocation studies. These methods were critically evaluated by Pallas and Crafts (10), and recently described in detail by Yamaguchi and Crafts (21). In an attempt to study the absorption and translocation of MH*[5] and amitrol*, barley plants were treated with various concentrations of endothal both foliar-applied and root-absorbed from culture solutions. Each tracer was applied in a single drop in the middle of the first leaf. Ten lambdas of a 50% alcoholic solution of MH* with ½ μc of the specific activity of 0.75 mc/mM, and 5 lambdas of aqueous solution of amitrol*, with ½ μc of the specific activity of 1.3 mc/mM, were applied per drop. Micropipettes delivering these amounts were used. A starch-hardened lanolin ring confined the drop.

In one experiment, roots of barley were exposed to 3 different concentrations of endothal, 3, 9, and 27 ppm, for 8 hours, then returned to Hoagland's solution. Twenty-four hours later the tracer was applied to the leaf as described. At either 8 or 48 hours after tracer application, the plants were harvested, quick-frozen with dry ice, and vacuum dried at −7° C. The dried plants were mounted on white paper sheets and autographed for 5 days on Kodak No-Screen X-ray film.

In another translocation experiment, solution-grown barley was sprayed with various concentrations of endothal (0.0075, 0.015, 0.03,

[5]The asterisk denotes radioactivity.

0.06, and 0.12%) with Vatsol added to each at 0.025%, at either 4 or 24 hours before the tracer application. Forty-eight hours after tracer application, the plants were frozen, dried, and autographed as above.

Respiration studies. The respiration studies using barley root tips and barley leaf segments were carried out on a Warburg respirometer, according to the Direct Method technique described by Umbreit et al. (20). Leaf segments 1-cm long were collected from the second leaf of barley plants having at least three fully developed leaves. Ten segments were used in each flask. The experimental solutions contained 0.2% MH, 0.1% endothal, or MH 0.2% + 0.1% endothal, and were prepared with M/50 or M/100 phosphate buffer pH 6.0. The temperature was 30° C., and the running time 2.5 hours.

Grains were germinated and root tips collected following the procedure outlined by Naylor and Davis (9), with minor changes. Either 15 or 20 tips 1-cm long were employed per flask. The temperature was again 30° C. In one experiment the root tips were treated for 2 hours with experimental solutions made up with half-strength Hoagland's solution adjusted to pH 6.0, then transferred to the respiration flasks.

RESULTS

Greenhouse experiments.

The results reported in Table 1 indicate that combination sprays of endothal with MH, applied either simultaneously or separately, were consistently more toxic than either chemical alone, even when the sprays were spaced in time by 1 week. The greater fresh weight of barley plants sprayed with the two toxicants with a 1 week interval

Table 1. Mean fresh weight of tops of barley plants 17 days after spraying. All solutions contained 0.05% Vatsol OT.

Treatment	Fresh weight grams
Check—no treatment	8.2
0.05% Vatsol	8.5
0.2% MH + 0.01% endothal	2.8
0.2% MH + 0.03% endothal	1.3
0.2% MH + 0.06% endothal	1.8
0.2% MH + 0.03% endothal immediately	1.4
0.2% MH + 0.03% endothal after 1 day	2.8
0.2% MH + 0.03% endothal after 2 days	1.5
0.2% MH + 0.03% endothal after 1 week	3.8
0.03% endothal + 0.2% MH immediately	0.6
0.03% endothal + 0.2% MH after 1 day	0.4
0.03% endothal + 0.2% MH after 2 days	1.7
0.03% endothal + 0.2% MH after 1 week	4.4
0.2% MH	5.0
0.01% endothal	7.8
0.03% endothal	6.4
0.06% endothal	6.0
LSD 5%	1.3

probably is due to slight growth in the intervening week. One day after spraying, the plants treated with both chemicals on the same day were wilted in direct proportion to the concentration of endothal

used, while only slight wilting was noticed in response to the two higher concentrations of endothal used alone. A similar trend as to the degree of injury was observed on the third day after the spraying. The two chemicals were always more injurious than endothal alone, irrespective of being applied together or separately. This degree of injury was apparently well measured by the fresh weight of the plants. The meaning of the term "fresh weight" is broadened to include plants that consisted of a complex of dry, injured and living tissue.

Subsequently other experiments were performed in which barley plants were treated with endothal concentrations low enough to preclude rapid burning of the leaves. Repeated applications of these low concentrations also were tried. Again, the MH-endothal combinations consistently produced more contact injury than the same concentrations of endothal used alone. The fresh weights did not show always a significant difference between the MH and MH-endothal treatments. Apparently MH was the factor controlling growth in these treatments.

One experiment with bermudagrass showed the same pattern of behavior as that described for barley plants (Figures 1, 3). Because

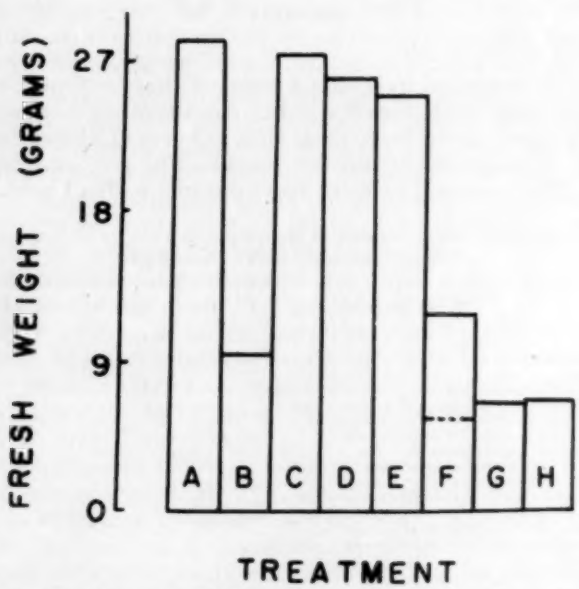

Figure 1. Average fresh weight of bermudagrass shoots 40 days after spraying. All solutions contained 0.05% Vatsol OT. A—0.05% Vatsol (control), B—1% MH, C—1% endothal, D—0.5% endothal, E—0.1% endothal, F—1% MH + 1% endothal, G—1% MH + 0.5% endothal, H—1% MH + 0.1% endothal. The LSD (5%) for the experiment is indicated by the distance from the dotted line to the top of bar.

of its marked growth-inhibiting action, the high concentration of MH (1%) employed did not show statistically-significant differences in fresh weight between MH and MH-endothal treatments. However, the combinations injured the leaves, especially the lower ones, more rapidly and to a greater extent than the endothal when used alone. Thus, the lower leaves of the plants sprayed with combinations were drying out one day after the spraying, whereas this symptom was not observed until the third day after the spraying in the endothal treatments. The effect was directly correlated to the endothal concentration, whether applied alone or in combination with MH. MH produced typical symptoms associated with growth inhibition (4), but no necrosis nor abnormal growth within the duration of the experiments.

Regrowth of the bermudagrass plants was observed 5 weeks after the tops were harvested (clipped to 1 cm above the soil). Normal regrowth (equal to the control) occurred in the endothal-alone treatments and in the combinations of MH with 1% endothal, but no regrowth was noted in the 1%-MH-alone and MH-1% treatments with either 0.5% or 0.1% endothal.

It is interesting that the same concentrations of endothal that were practically without effect on bermudagrass completely killed barley plants. These results are in accord with the work of Tischler et al. (18). In their paper may be found an extensive list of susceptible, intermediate, and resistant plants with reference to endothal tox-

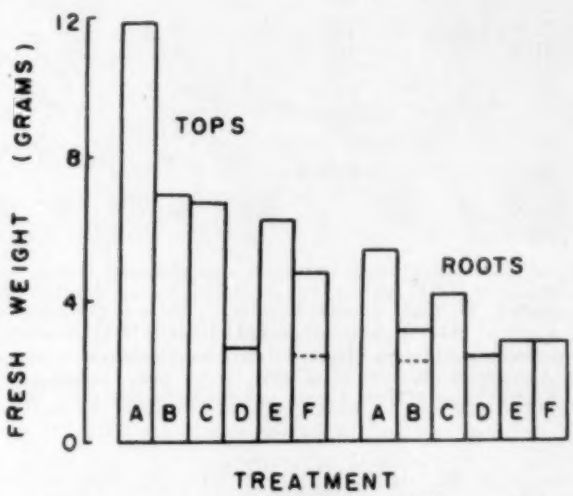

Figure 2. Average fresh weights of tops and roots of solution-grown barley plants, root-treated for 8 hours, harvested 12 days later. A—control, B—500 ppm MH, C—9 ppm endothal, D—27 ppm endothal, E—500 ppm MH + 9 ppm endothal, F—500 ppm MH + 27 ppm endothal. The LSD (5%) for each experiment is indicated by the distance from the dotted line to the top of bar.

icity, barley being classed as susceptible and bermudagrass as resistant.

Where the toxicants were applied to the culture solution and were absorbed by the roots of barley plants, a somewhat different picture was revealed, in that MH had no effect on the toxicity of endothal (Figures 2, 3). The degree of injury was exclusively dependent upon

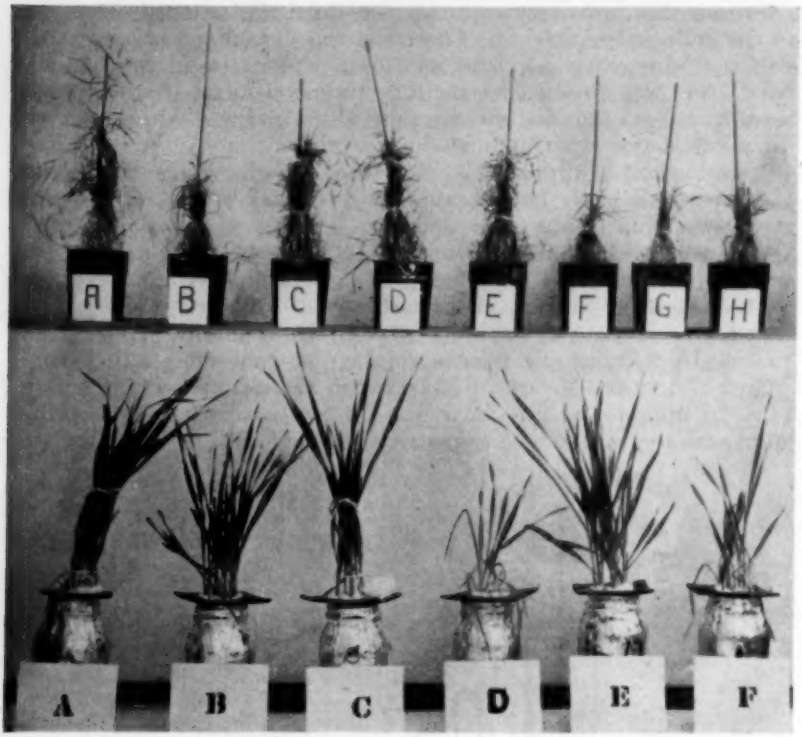

Figure 3. Upper: Bermudagrass 40 days after spraying with various solutions. All solutions contained 0.05% Vatsol OT. A—0.05% Vatsol (control), B—1% MH, C—1% endothal, D—0.5% endothal, E—0.1% endothal, F—1% MH + 1% endothal, G—1% MH + 0.5% endothal, H—1% MH + 0.1% endothal. *Lower:* Solution-grown barley plants 12 days after root-treatment with various solutions. A—control, B—500 ppm MH, C—9 ppm endothal, D—27 ppm endothal, E—500 ppm MH + 9 ppm endothal, F—500 ppm MH + 27 ppm endothal.

the endothal concentration. However, the degree of injury was not very uniform among the replicates of a given treatment. Since the plants were very similar at the beginning of the experiment, this fluctuation can be attributed to unequal uptake of the chemicals by the plants of each replicate.

Translocation studies. The studies with labeled MH and amitrol were initiated to test the hypothesis that endothal interference with

the translocation of other chemicals could account for some of the results and observations reported in the literature.

It is known that endothal is absorbed readily by roots and translocated upward (8, 11, 12, 19). Root applications to transpiring plants would assure the presence of the chemical throughout the plant. The results presented in Figure 4 represent a sample of the translocation studies in which endothal was absorbed by the roots and MH* and amitrol* were applied dropwise to the first leaf. Eight hours after MH* application, radioactivity was present throughout the plant in the low-endothal treatment (equal to the control), and almost confined to the treated leaves in the two other (higher) concentrations of endothal. Amitrol* did not translocate from treated leaves in any of the three endothal treatments, and in the two lower endothal concentrations it remained limited to the portion of the leaves above the treated spot.

Forty-eight hours after tracer application, the translocation of both MH* (Figure 4) and amitrol* was inhibited in proportion to the amount of endothal added to the culture solution, judging from the autographs. The lowest endothal concentration had little effect, observable only in the MH*-treated leaf; the tracer did not move in the treated leaf to the extent that it did in the control plant. MH*, in the endothal-treated plants, remained more concentrated around the treated spot, whereas amitrol* spread toward the tip.

In the plants sprayed with a series of low concentrations (0.0075 to 0.12%) of endothal 4 and 24 hours before the tracer application, a marked retardation of MH* translocation could be observed only in one plant, one that was severely injured. Since a low concentration of surfactant was used in combination with endothal, it is assumed that the penetration of endothal was insufficient to produce a detectable effect.

Respiration tests. If MH and endothal interact on the cellular level, one plant process likely to be affected is respiration. This is the reason for the respiration (oxygen uptake) measurements on leaf segments and root tips. The references in the literature generally point to MH as a respiration inhibitor, and to endothal as a respiration stimulant. Thus, Naylor and Davis (9) measured the respiration of root tips of several plants placed in contact with five different concentrations of MH, at pH 6.0, and pH 4.0. The respiratory rate was not greatly affected by MH at pH 6.0, but at pH 4.0 a marked inhibition resulted. Barley root tips were the most sensitive, the respiration at pH 4.0 in 0.2% MH being 32% of the control. Isenberg et al. (7) determined the respiratory rate of mature onion bulbs harvested from plants sprayed with several MH concentrations and with varied rates of application. A stimulation of respiration by low concentrations, and an inhibition by high concentrations of MH were found. For cotton leaf disks taken from plants sprayed with 500 ppm of MH, Dawson[6] observed a stimulation of respiration,

[6]The effect of maleic hydrazide and magnesium on the respiration of cotton plants. M.S. Dissertation, University of Chicago, 1955.

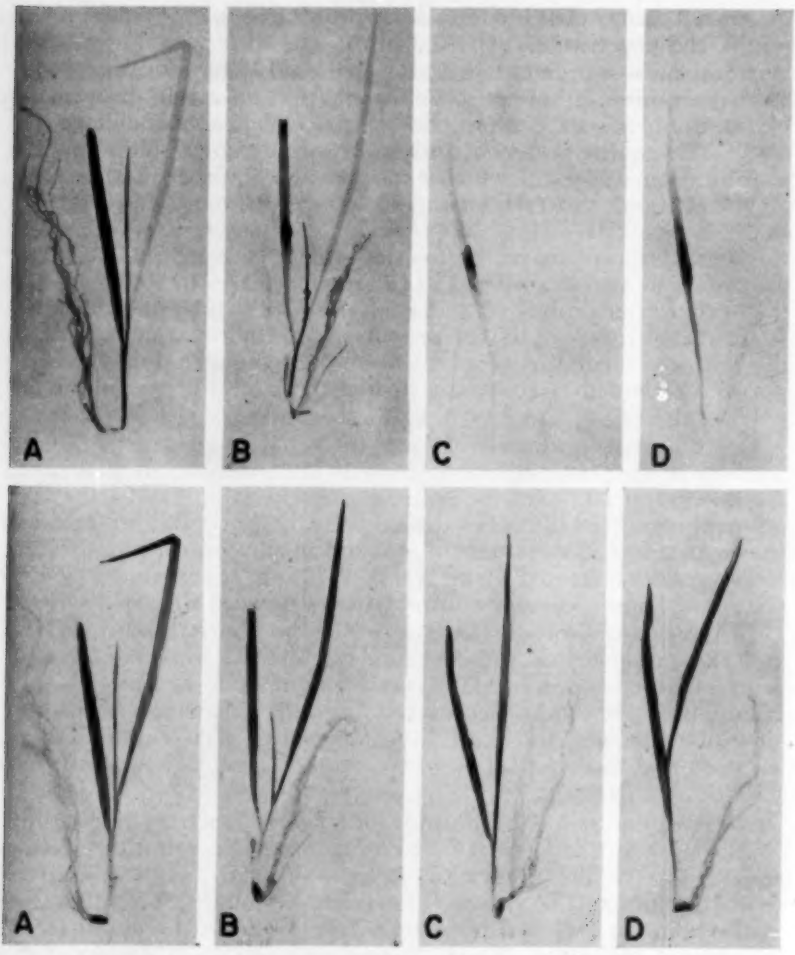

Figure 4. Radioautographs (upper series) of barley plants (lower series) spot-treated with C^{14}-labeled-MH for 48 hours. Twenty-four hours before the tracer application, the plants were exposed for 8 hours to Hoagland's solution containing the following endothal concentrations: A—0 ppm, B—3 ppm, C—9 ppm, D—27 ppm.

followed by an inhibition, a secondary stimulation, and a secondary inhibition. The respiratory rate of red kidney bean plants, which received MH in the culture solution at concentrations from 100 to 200 ppm, was stimulated at first, a peak being reached in about four days, and then a steady decline followed (16).

The results presented in Table 2 were very consistent. Thus, the respiratory rate of barley leaf segments was decreased by MH, and increased by endothal, in a short term experiment. The combination

of the two chemicals gave a stimulation about equal to that produced by endothal alone.

Table 2. Respiration of barley leaf segments. $\mu l/O_2$/mg dry weight/hr measured one hour after application of chemicals.

Treatment	Replicates		Mean	Relative rate
	A	B		
Buffer alone (control)	1.81	1.80	1.80	100
0.1% endothal	2.65	2.34	2.49	138
0.2% MH	1.24	1.28	1.26	70
0.1% endothal + 0.2% MH	2.22	2.31	2.26	125

The respiratory rate of barley root tips was determined by a method similar to that used in the previous experiment, except that the buffer was more dilute (M/100), and presented the same trend as that obtained with leaf segments. There was one difference, in the combinations the respiratory rate was lower than that of the control. However, the results were not very consistent for considerable fluctuation occurred within each treatment. Use of half-strength Hoagland's solution adjusted to pH 6.0 in one experiment failed to show any difference between treatments.

DISCUSSION

In the greenhouse experiments, two different effects could be distinguished, a chronic growth inhibition due to MH, and an acute burning (necrosis) caused by endothal. In the treatments involving both chemicals, these two effects could not always be separated by fresh weight measurements. Registered visual symptoms supplemented such measurements, and all of these data pointed to an increase in the contact action of endothal when MH also was present in the treatment.

One hypothesis that may explain very well the data obtained in the greenhouse experiments is that the MH formulation employed enhances the effectiveness of endothal by increasing its penetration into the leaves. The evidences in support of this hypothesis may be summarized as follows: (a) The contact action of endothal appeared earlier in the plants sprayed with both chemicals than in plants sprayed with endothal alone. (b) A lower concentration of endothal was required when combined with MH to produce a certain degree of injury than when applied alone. In other words, MH increases the effectiveness of endothal. (c) Bermudagrass, which is quite resistant to endothal, was slightly injured (lower leaves only) by this toxicant at the concentrations used, whereas almost all leaves were burned by the MH-endothal combinations. (d) In the culture solution experiment where the chemicals were applied through the roots, thus eliminating the leaf cuticle barrier, MH had no effect on the toxicity of endothal. (e) Literature references have indicated that endothal is not readily absorbed by the leaves (8, 19), and that

adjuvants such as surfactants (19) and ammonium sulfate (12, 18, 19), greatly increase its penetration and hence its effectiveness.

In aiding the penetration of endothal MH may act as a surfactant, a humectant, or have a combination of effects. It was observed during the sprayings that the solutions containing both MH and endothal did wet and spread over the leaves consistently better than the endothal solutions. It is to be noted that all solutions contained 0.05% Vatsol OT, which, one can conclude, was not enough to give good surfactant action in the case of endothal solutions. The importance of humectants in the foliar penetration of MH was recently stressed by Zukel et al. (22).

It has been reported that endothal is not translocated downward appreciably (8, 11). To explain this phenomenon, Poland (11) accepted the hypothesis that phytotoxic substances are able to move through the dead elements tissues, but kill living phloem tissues, thereby interfering with subsequent downward movement. The results obtained in the tracer experiments indirectly support this hypothesis and, in addition, show clearly that endothal when applied to the roots, even at sub-lethal doses, interferes with the movement of substances out of leaves. This movement is presumed to occur through the phloem tissues.

How endothal affects living cells, including the phloem cells, is not known. Currier (2) observed an increase in dispersion and swelling of protoplasm and an abnormal pattern of protoplasmic streaming in leaves of *Anacharis canadensis* subjected to endothal treatment. These responses were associated with a marked increase in respiratory rate. Hall (5) reported that a 2% endothal spray reduced the respiratory rate of detached cotton leaves for about 2 hours, and then increased the rate to about twice that of the control.

Considering, then, that endothal is too toxic to be translocated in the phloem, it also seems to prevent the translocation of other substances (MH and amitrol). With reference to defoliation phenomena, these findings are not in accord with the idea that defoliants promote the movement of some factor from the blade to the abscission zone. As to the effects on regrowth, assuming that the defoliant causes disruption of the phloem and prevents the normal downward transport, it is expected that growth inhibitors applied in combination with endothal do not control regrowth if the spray is limited to leaf blades only. But a spray covers all parts of a plant, and therefore a certain degree of inhibition, dependent on the amount of growth-regulator that reaches the buds, should be apparent. A differential penetration of the two chemicals also can occur when sprayed together, where MH may reach the buds before endothal reduces or stops the movement within the phloem.

Studies of respiratory activity are dependent upon several factors, such as pH (12), time (5, 16), concentration of toxicants (7), and also penetrability of the chemical. The inconsistency of some of the results mentioned herein can be understood when one takes into consideration the complex of factors operating at the same time.

SUMMARY

Possible interactions between maleic hydrazide and endothal were sought in barley and bermudagrass plants, using three types of experimental procedures: (a) greenhouse methods to determine toxicity, (b) radioautography to follow translocation, and (c) oxygen uptake to measure respiration effects.

From the results it is concluded that:

1. In foliar application MH (diethanolamine salt) enhances penetration and subsequent acute toxicity of endothal. Such enhancement was not observed in root application.

2. Endothal, with increasing concentration, gives increasing acute toxicity regardless of the presence of MH. This effect is in sharp contrast to the slow-developing chronic type of MH injury.

3. At a certain concentration level, however, endothal prevents the systemic downward movement of MH. Under these conditions endothal is antagonistic to MH, probably due to toxic effects on phloem cells. Such antagonism was clear in barley where endothal was applied to the roots, and in foliar-sprayed bermudagrass. It was not apparent in foliar-sprayed barley.

4. A few short term respiratory rate measurements using a Warburg apparatus confirmed previous reports that MH is generally an inhibitor, and endothal a stimulant of respiration; but as to possible interactions of these two toxicants on the cellular level, the results are inconclusive.

ACKNOWLEDGMENTS

Thanks are due the Naugatuck Chemical Division, U. S. Rubber Co., for providing MH-30 and C^{14}-labeled-MH; to the Niagara Chemical Division, Food Machinery and Chemical Corporation, and to the Pennsylvania Salt Co., for supplies of endothal; to the American Chemical Paint Company for the labeled amitrol; and to the American Cyanamid Company for Vatsol OT.

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BRIEF PAPERS

Rating Scales for Weed Control Experiments

C. J. WILLARD[1]

IN many types of weed control experiments most economical progress can be made by visual rating of the plots. While such ratings are admittedly somewhat subjective, this does not necessarily mean that the results are less accurate or less satisfactory than methods which profess to be quantitative. For example, counting thistle sprouts in a square-rod area may show more sprouts in a treated plot than in the check because the herbicide used resulted in a number of weak sprouts replacing every strong sprout killed to the ground line. If only counts are made, the data will look as if no progress was being made, while if both the strength and number of sprouts are rated the actual situation will be much more nearly approximated.

One does not need to argue today about the value and need of rating systems for weed control plots. The writer made a hasty search through one report of one regional weed control conference. This very hasty survey turned up 11 papers in which all or part of the data were given by rating scales. What was particularly unfortunate was that in these 11 papers no less than eight different scales were used. One scale was used in three papers, another in two, and the writers of each of the other papers used different scales. More uniformity in the rating scales used would help to make reading weed control literature less difficult for the reader.

What are some of the requirements for a satisfactory plot rating scale?

1. The scale should have a sufficient number of classes so that those differences which are readily observable can be expressed by the scale chosen.

This principle, one of the most elementary statistical principles, is perhaps the one most frequently broken. Many rating scales extend only from one to four, one to five, zero to five, etc. Such scales definitely do not furnish as many classes as are required to make a satisfactory rating of practically any experiment. One end of any scale must be used for "no effect" the other for "everything killed." If you have only 5 classes, that leaves only three degrees of effect, aside from the ends, to be expressed by your scale. It is a rare experiment which does not deserve closer rating than this.

2. The classes chosen for the rating scale should be reasonably capable of description. The limits of the scale must be clear and some idea of the meaning of the intermediate points should be given.

3. The classes in a suitable scale should be capable of being arithmetically averaged without undue distortion. This means that the weed control value of the steps in the scale must be as nearly equal as possible.

[1]Department of Agronomy, The Ohio State University, Columbus 10, Ohio.

Of the many scales in use, the writer would like to suggest that a scale of zero to ten, using zero for no effect, or the check, and ten for the maximum possible effect, which usually is everything killed, is better adapted to weed control work than any other scale. The number of classes is perhaps not quite sufficient, but if in a large experiment it is desired to indicate something between two classes a half-way point can readily be indicated by adding 0.5. The scale then automatically becomes a percentage classification. Keeping everything in a decimal classification simplifies estimation and notation to a very great extent. It is one of the great advantages of this system that it is completely compatible with percentage estimations where these can be made.

Many scales use one as "no effect". The discovery of zero was one of the great advances in mathematics and it seems that use should certainly be made of it to indicate complete lack of effect.

Several scales which the writer has seen end with nine instead of ten. Although nine or ten classes are better than four or five, it is difficult to see an advantage in making the final class nine and hence sacrificing the ready transformation to and from percentages which the zero to ten system makes possible.

The question of which to make the top and which to make the bottom of the scale is not an entirely irrelevant one. Some papers use nine or ten for no damage and one or zero for complete kill. While there is a way of thinking which could justify this, from the point of view of studying treatments and herbicides the use of the lowest value for "no effect" and the highest value for "maximum effect" is more nearly in accord with our ordinary habits of thought.

One of the most confusing systems of rating consists in using the low end of the scale for "no effect" on weeds, and the high end of the scale for "no effect" on crops, in the same paper. It would seem that injury to crop plants should certainly be rated in the same manner as injury to weeds.

Effect of Maleic Hydrazide on Some Tropical Lawn Grasses

H. J. Cruzado and T. J. Muzik[1]

It has been reported that the frequency of mowing lawns in some areas of the United States can be markedly reduced by the application of maleic hydrazide (3). Other investigators have reported a retardation of growth but no reduction in number of mowings and a scorched appearance (1, 2). To determine whether this practice is practical under tropical conditions, an experiment was conducted utilizing a number of important tropical lawn grasses.

Five tests were performed, one with each species of the following lawn grasses: Manila grass *(Zoysia matrella* (L.) Merr.), sour paspalum *(Paspalum conjugatum* Berg.), centipede grass *(Eremochloa ophiuroides* (Munro) Hock.), Java grass *(Polytrias praemorsa* (Nees) Hack, and carpet grass *(Axonopus compressus* (Sw.) Beauv.). All of the experiments were designed in randomized blocks, with five treatments replicated four times. The individual plots were 25 feet by 3⅓ feet. A 1-foot border was left between all plots. The treatments consisted of the diethanolamine salt of maleic hydrazide (MH) at 0, 2, 4, 8, and 16 lb/A (active ingredient), applied with knapsack sprayers, in aqueous solution at a volume of 200 gallons per acre.

In all experiments, the chemical was sprayed about 2 weeks after cutting when the plots had vigorous young growth. Eight weeks later, the plots were mowed lengthwise through the center of each plot with a 3-foot wide mower, with the cutting bar adjusted to cut 1 inch above the ground level. The cut grass was collected and weighed. Total rainfall during the period of the experiment was as follows: January, 1.8 in.; February, 0.3 in.; and March, 4.9 in.

The growth of only one species, centipede grass, was significantly reduced by MH. Compared to the check the difference was significant at the 5 percent level. Growth was not significantly reduced in any of the other grasses as shown in Table 1. Observations made during the experiment showed that the appearance of all the grasses, except Manila grass, was adversely affected by the application of 4 or more pounds of MH per acre. At this rate of application, the Java grass plot was gray and dry 8 weeks after treatment. Two weeks after treatment, all of the carpet grass plots showed a red coloration, with the exception of the check. This effect persisted until the final data were taken in the plots with the 8- and 16-pound applications. At the end of 8 weeks, sour grass and centipede grass plots in the 8- and 16-pound applications showed a pronounced brownish-gray color.

Manila grass, which was the lawn grass least adversely affected by the chemical, showed other responses. Flowering and seeding were

[1]Agronomist, Federal Experiment Station, Mayaguez, Puerto Rico, and formerly Plant Physiologist, Federal Experiment Station, Mayaguez, Puerto Rico, now Associate Professor, State College of Washington, Pullman, Washington, rspectively.

Table 1. The effect of spray applications of maleic hydrazide on the growth of some tropical lawn grasses.[a]

Lawn grasses	Dry weight grass harvested after maleic hydrazide applications (lb./acre)					Difference required for significance at 5% level
	0	2	4	8	16	
	Gms.	Gms.	Gms.	Gms.	Gms.	
Manila grass	29.3	31.0	18.5	22.3	25.8	Not significant
Sour paspalum	199.8	372.0	258.8	250.5	215.0	Not significant
Centipede grass	152.3[b]	87.3	108.5	82.5	91.8	43.5
Carpet grass	22.0	36.5	19.0	17.3	22.0	Not significant
Java grass	88.5	86.5	53.3	69.5	56.0	Not significant

[a]Average dry weight of grass clippings from four plots, 75 square feet each, mowed to within 1 inch of the ground.
[b]Significantly greater weight of clippings than any of maleic hydrazide treatment plots.

profuse in the check, 2- and 4-pound per acre plots, but were very sparse in the 8- and 16-pounds per acre plots. Two noxious weeds, (*Meibomia* sp. and *Alysicarpus vaginalis* (L) DC), which are very common in lawns of this species, grew extensively in the border rows, checks, and the 2-pound per acre plots. They were well controlled at the higher rates of application.

These results indicate that under the conditions of this experiment, the application of maleic hydrazide to tropical lawn grasses had an adverse effect on color of the grass and did not reduce growth in most species sufficiently to warrant practical usage. It should be pointed out, however, that these tests were made during the dry season, and that different results might be obtained if tests were run under conditions of higher rainfall. Zukel (4) has shown that the action of MH is greatly affected by humidity.

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Minutes of the Business Meeting and Committee Reports, Weed Society of America Meeting, January 13, 14 and 15, 1958.

Minutes

The second General Business Meeting of the Weed Society of America (WSA) was held at the Hotel Peabody, Memphis, Tennessee, at 4 pm, January 13, 1958. The meeting was called to order by W. B. Ennis, Jr., President of the Society. He expressed his appreciation for the excellent work of the various Standing and Special Committees and especially for the full cooperation that he had received from the membership of the Society. He emphasized that the Society exists to serve the needs of the members, and that the ideas and suggestions of the members should be continuously solicited in an effort to improve WSA.

The minutes of the first Business Meeting of the Society, January 4, 1956, as published in Weeds 4 (4):400–404. 1956, were read by W. C. Shaw, Secretary, and were approved as read.

Dr. Ennis then gave a report on the Society's activities for the period January 1956 to January 1958. He indicated that the membership was increasing and that the financial status of the Society was sound.

He described the work of a special committee which had been appointed to work with the National Research Council in developing information on losses caused by weeds. C. A. Sears is Chairman of the committee.

It was also indicated that C. J. Willard would become the Editor of WEEDS December 1, 1958, replacing K. P. Buchholtz, who now fills this position.

The Constitution and By-Laws Committee, headed by C. J. Willard, is revising the Constitution of the Society. The revision is scheduled to be completed before 1960 for membership consideration before or at the 1960 meeting.

W. B. Ennis announced that the Executive Committee voted unanimously to accept the application of the National Weed Committee of Canada for conference membership in WSA. This application for membership will be voted on by the Society members in the next regular mail ballot.

W. C. Jacob, Treasurer-Business Manager of the Weed Society of America, presented a detailed report on the membership and business affairs of the Society. An Auditing Committee report was presented by F. W. Slife indicating that the financial report of the Society was correct as presented by Dr. Jacob.

Standing and Special Committee reports were presented by the Chairman of each committee. The Chairman of each committee moved the adoption of his respective report. In the case of each report, the membership of the Society voted acceptance.

O. C. Lee moved that the Education Committee report be mimeographed by the Society and circulated to the membership for review. The motion seconded by G. C. Klingman carried.

F. W. Slife's Finance Committee report included a recommendation which will require action by the new Executive Committee, and it was requested that the recommendations in his report be called to the attention of the new Executive Committee.

In the discussion following the presentation of the Terminology Committee report, it was suggested that the committee consider issuing the report quarterly as soon as possible. It was also suggested that the list of common names being developed by the subcommittee be circulated widely before adoption.

The Resolutions Committee report was discussed and Resolutions 1, 2, 3, and 4 were accepted by the membership without change. C. J. Willard suggested that Resolution 5 be edited to delete any suggested names for the discipline of weed control, and that this matter be referred to the newly elected Executive Committee for further study and appropriate action. Motion was seconded by W. R. Furtick. Motion carried.

The next meeting of the Weed Society of America is scheduled to be held in Denver, Colorado, February 22–25, 1960.

W. C. SHAW, *Secretary*

STANDING COMMITTEE REPORTS

FINANCIAL REPORT, WEED SOCIETY OF AMERICA, DEC. 1, 1956 TO NOV. 30, 1957.

Balance on hand Dec. 1, 1956			$8,128.73
RECEIPTS			
Memberships and subscriptions			
Volume 1	$ 106.04		
Volume 2	93.00		
Volume 3	115.00		
Volume 4	149.00		
Volume 5	5,148.50		
Volume 6	3,095.25		
Total		$8,706.79	
Reprints			
Volume 4	155.95		
Volume 5	862.90		
Total		1,018.85	
Advertising			
Volume 5	1,300.00		
Volume 6	100.00		
Total		1,400.00	
Sustaining membership			
1958	2,500.00		
Total		2,500.00	
Abstracts	15.00		
Total		15.00	
Total			13,640.64
		TOTAL RECEIPTS	$21,769.37

EXPENDITURES				
General Operating Expenses				
Office supplies	98.95			
Mimeographing	27.37			
Postage and communications	577.05			
Secretarial labor	1,207.25			
Honorarium to Editor & Bus. Mgr.	600.00			
Bank expense	6.30			
Travel expense	56.41			
Treasurer's bond (3 yrs)	62.50			
Total		2,635.83		
Publications				
Printing of WEEDS	5,514.68			
Reprints	864.80			
Refunds	28.00			
Total		6,407.48		
TOTAL EXPENDITURES			9,043.31	
TOTAL RECEIPTS				21,769.37
TOTAL EXPENDITURES				9,043.31
BALANCE ON HAND DEC. 1, 1957				$12,726.06

WALTER JACOB, *Treas. and Bus. Mgr.*

PROGRAM COMMITTEE.

Thanks were expressed to the members of the committee for their assistance in developing the program. The committee also expressed its appreciation for the fine cooperation of the Southern Weed Conference as Host for the second meeting of the Weed Society of America. The committee extended special thanks to the Local Arrangements Committee for their excellent cooperation in obtaining facilities and equipment, and for making other arrangements in connection with the program.

A. S. CRAFTS
G. D. HILL
W. K. PORTER, JR.
G. F. WARREN
W. C. SHAW, *Chmn.*

TERMINOLOGY COMMITTEE.

A brief description of the objectives and accomplishments of the committee was presented. Two sub-committees have been appointed to assist in the development of terminology used in the field of weed control. These sub-committees are:

Sub-committee on Standardization of Abbreviations, Terms, and Definitions Used in Weed Control. K. P. Buchholtz, R. D. Sweet, F. L. Timmons, R. Behrens, Chairman

Sub-committee on Standardization of Common and Botanical Names for Weeds. L. C. Erickson, W. R. Furtick, L. G. Holm, M. M. Schreiber, R. A. Darrow, Chairman

Both of these sub-committees have made excellent progress in developing standardized terminology in their areas of responsibility. An attempt will be made to revise the Terminology Committee report at least biannually. The work of the two sub-committees will be included in an early revision of the report. The Chairman expressed his thanks to the members of the committee for their assistance and excellent cooperation in developing the Terminology Committee report. The detailed report of the committee is published in WEEDS 6 (1):71–76. 1958.

W. C. SHAW, *Chmn.*

EDITORIAL COMMITTEE.

Since January 1, 1956, Volumes 4 and 5 of WEEDS have been published. Issue 1 of Volume 6 was mailed a few days ago. At present, Issue 2 of Volume 6 is in the hands of the printer and Issue 3 is in the process of preparation. During the past 2 years, publication date has not deviated more than a few days from the January 1, April 1, July 1 and October 1 dates desired for a quarterly journal.

Publication of WEEDS on a regular schedule is in large measure due to the excellent cooperation of all members of the Editorial Committee now including O. C. Lee, R. A. Peters, W. C. Robocker and E. G. Rodgers. Previously R. J. Aldrich and W. K. Porter, Jr. also served on the Editorial Committee. The WSA is indebted to these men for the considerable time and care they have devoted to the review of manuscripts. I wish to thank Walter Jacob, Business Manager and Treasurer of WSA, for his excellent work in circulating the galley proofs and returning them to the printer so promptly. Finally, I wish to thank the many authors themselves for the prompt attention given the page proofs for without their cooperation regular publication would be impossible.

During the past 2 years we have received 112 manuscripts for publication. Seventy-two of these have been published. Fourteen are awaiting publication, 10 have been returned to the authors for revision and 9 are in the hands of reviewers. Seventeen manuscripts have been rejected or withdrawn. A significant number of the manuscripts rejected had been published previously in virtually the same form in one of the regional weed conference publications.

In Volumes 4 and 5 of WEEDS an average of 64 pages of text were devoted to manuscripts in each issue. During the past few issues this has been increased somewhat for the supply of papers has improved. It is our hope to be able to publish approximately 100 pages of manuscript in each issue. To do so we must have an even larger supply of good original manuscripts dealing with all phases of weed control than we have received during the past 2 years. We believe that many of the papers presented during this meeting of the WSA are worthy of submission to WEEDS for publication. These may include papers on investigations dealing with all aspects of weed development and distribution, studies on competitive effect of weeds, responses of weeds and crop plants to herbicides, sum-

maries of weed regulatory activities and papers dealing with educational and extension efforts in weed control. These manuscripts will be reviewed and accepted for publication in the same manner as are other papers intended for publication in WEEDS. We ask your continued interest in WEEDS as a journal for the publication of your more detailed, comprehensive and worth while papers in the field of weed control. In return the Editorial Committee will endeavor to prepare and publish a journal that will be of value to you individually and to the field of weed control in general.

K. P. BUCHHOLTZ, *Chmn.*

EDUCATION COMMITTEE.

The previous Education Committee, in their report given at New York in 1956, outlined several objectives, aims and duties of future committees. They include among others:

Promote the graduate and undergraduate curriculum in weed control by:

(a) Developing a list of courses that is considered important in the field and establish a rating of such courses.

(b) Develop a list of schools offering weed courses.

A list of courses considered by the committee to be essential in a study program of a student preparing for work in weed control has been prepared. This includes both undergraduate and graduate courses. They are listed in four groups, (1) essential, (2) highly desirable, (3) desirable, and (4) helpful.

A survey of Land Grant College catalogues revealed that 28 colleges or universities offer one course in weeds or weed control, 14 offer two and three offer three courses. Others do not have courses listed under the heading weeds or weed control.

K. P. BUCHHOLTZ
W. R. FURTICK
G. C. KLINGMAN
L. I. KING
O. C. LEE, *Chmn.*

FINANCE COMMITTEE.

The Committee recommends that when surplus funds become available from the Society that they be invested either in government bonds or in a federally insured savings account. Although the interest rate is not as high as might be obtained elsewhere, the invested money would be readily available on short notice and would draw a reasonable profit without excessive gamble.

T. R. COX
A. D. LOHR
S. M. RALEIGH
E. G. RODGERS
F. W. SLIFE, *Chmn.*

LEGISLATIVE COMMITTEE.

The Committee submits the following for the consideration of the Society:

1. There has been no change in the past 2 years in the number of states having herbicide application laws.

2. There is definite need to have representatives from the four regions of the U. S. and Canada on the Legislative Committee.

3. The Society should encourage the publication of more papers containing factual information pertaining to the regulatory and legislative phases of weed control in the journal, WEEDS, and other publications.

4. The Society should encourage closer cooperation with pesticide control officials, weed supervisors, seed and feed control officials, and other control officials who have an interest in weeds and their control.

5. The Society should undertake a review of all laws and regulations pertaining to weeds and their control, namely weed and seed laws, feed laws, or other similar laws and regulations that have an affect on the distribution and control of weeds and weed seeds.

6. The Legislative Committee recommends that the Weed Society of America draft a resolution in support of bills introduced in Congress to provide for the control of noxious weeds on land under the control or jurisdiction of the Federal Government in states where a program is in effect for the control of noxious weeds.

JACK DREESSEN
E. A. EPPS
C. J. GILBERT
W. E. LOOMIS
W. S. BALL, *Chmn.*

NOMINATING COMMITTEE.

The Committee nominated the following candidates for office:

President	A. S. Crafts
	W. A. Harvey
Vice President	K. P. Buchholtz
	F. L. Timmons
Secretary	W. C. Shaw
	F. W. Slife

The following officers were elected by mail ballot:

A. S. Crafts, President
K. P. Buchholtz, Vice President
W. C. Shaw, Secretary

R. J. ALDRICH
D. W. BOHMONT
D. W. LAMBERT
D. E. WOLF
G. C. KLINGMAN, *Chmn.*

SPECIAL COMMITTEE REPORTS

AUDITING COMMITTEE

The Committee examined the financial records of the Weed Society of America as kept by W. C. Jacob, and found them to be in proper order. The audit completed includes the records from November 30, 1956 to November 30, 1957.

E. B. HOLLINGSWORTH
G. F. WARREN
F. W. SLIFE, *Chmn.*

MEMBERSHIP COMMITTEE.

The membership of the Society has increased to 660 individuals during the last year. It is proposed to increase the size of the committee to include key persons in each state so that a concerted effort can be made to enroll all persons doing weed work.

The mailing list of the Society includes also 162 libraries, 205 subscribers to the Journal and 23 sustaining members. Renewals for 1958 have been coming in at a good rate. About 80% of the total mailing list has been renewed.

WALTER JACOB, *Chmn.*

SUSTAINING MEMBERSHIP COMMITTEE.

The sustaining membership in the Weed Society of America has increased from 20 members in 1956 to 25 members in 1958 with the resulting increase to sustaining membership donations from $2,000 to $2,500 per annum. For the 1957 sustaining membership drive approximately 140 organizations interested in the field of chemical weed and brush control were contacted. For the 1958 drive this number was increased to 170. The list of sustaining members includes chemical manufacturing companies, pesticide distributing companies, commercial brush control organizations, equipment manufacturing companies and the Association of American Railroads.

Each prospective member was contacted by means of a letter early in September. This was followed by a follow-up letter in October and in 1957 a letter of thanks was written by the President of the Society to each sustaining member in January of that year. For the 1958 sustaining membership drive an additional letter was written to various public utility companies urging that they show their interest in the Weed Society of America by becoming a sustaining member. The response to this letter was negligible.

The retiring Sustaining Membership Committee would like to suggest the following:

1. A letter of thanks similar to the one written in 1957 be written and signed by the new president early in 1958. This letter should go to each organization maintaining a sustaining membership.
2. A vigorous effort be made to interest public utility companies

or an association of such companies in becoming sustaining members of the Weed Society of America, because of their interest in right-of-way weed and brush control.

L. H. HANNAH
D. W. RAKE
L. SOUTHWICK
D. E. WOLF
E. R. MARSHALL, *Chmn.*

PUBLIC RELATIONS COMMITTEE.

The Committee reports the following activities and accomplishments during the past 2 years:

1. Three press releases pertaining to the Memphis meeting were sent to more than 200 publications and radio stations throughout the U. S.
2. A special news story pertaining to weed control in general for release January 13, 1958, was mailed to newspapers and magazines.
3. Arrangements were made with the National Farm and Home Hour for a special report on the Society's meeting to be broadcast on Saturday, January 18, 1958.
4. Cooperated with the USDA ARS Information Section, which prepared releases pertaining to ARS papers presented at the meeting.
5. Contacted local papers, radio and TV stations for coverage of the meeting.
6. Mailed releases to Experiment Station editors at the southern universities and colleges.
7. Mailed releases on the meeting to WSA members.
8. Arranged for TV show on Memphis station WMCT.

The Committee suggests the following items for the consideration of the Society:

1. Set up a professional press service for future meetings staffed by company or state experiment station publicity personnel.
2. For more effective coverage of meetings, papers should be submitted to the Committee in advance of WSA meetings.
3. Each regional weed conference should be represented on the Public Relations Committee.
4. Set up recording facilities for those who wish to record special subjects for use by their extension radio specialists.

H. J. CAREW
W. C. JACOB
LEONARD LETT
JACK DREESSEN, *Chmn.*

LOCAL ARRANGEMENTS COMMITTEE.

The Committee reports the following activities and accomplishments:

1. Contacted local hotels, Chamber of Commerce and other local groups in setting up the meeting.

2. Prepared or obtained the following material for the convention:
   (1) Suggested dining places in Memphis
   (2) Downtown Memphis map
   (3) Ladies entertainment schedule
   (4) Memphis guide
3. The Committee worked closely with the Program Committee in arranging for rooms, projection equipment and other items necessary for conducting the meeting.
4. Prepared information sheet giving details on hotel reservations, travel guides, banquet facilities, registration details and other pertinent facts about the conference. A copy of this sheet along with hotel reservation request forms sent to members of the WSA and SWC.
5. Planned entertainment for the ladies:
   (1) Get acquainted coffee hour
   (2) Bus tour of Memphis
   (3) Luncheon and fashion show

The Committee makes the following suggestions for the consideration of the Society:

1. Appoint a Committee chairman who lives in or fairly close to the city where Society will meet.
2. Allow the chairman of the Committee the privilege of selecting or adding to the Committee as needed.

J. T. HOLSTUN, JR.
H. A. NATION
W. K. PORTER, JR.
R. J. SMITH
LEONARD LETT, *Chmn.*

RESOLUTIONS AND NECROLOGY COMMITTEE.

Resolutions:

The Committee presented five resolutions. The first four were read and acted on as a group. These were as follows:

1. Whereas the Southern Weed Conference has been generous in its hospitality, and, Whereas the Local Arrangements Committee has done an excellent job arranging all the necessary details for our conference, and Whereas the officers and section chairmen of WSA have generously given of their time and energy to make this meeting a successful and memorable one,
   Be it therefore resolved that we gratefully acknowledge this service and hospitality.
2. Whereas our Society has been generously supported by financial contributions from Sustaining Members,
   Be it therefore resolved that we publicly acknowledge this valuable support at this business meeting and furthermore that the list of contributors be published in WEEDS and in future meeting programs.
3. Whereas our official journal WEEDS has attained increased stature as a scientific publication,
   Be it therefore resolved that we commend the editorial staff

for devoted and prodigious efforts which have resulted in great good for the new discipline of weeds and weed control as well as for the Weed Society of America.

4. Whereas basic research and economic evaluation research are both important to our new scientific discipline,
   Be it therefore resolved that this Society go on record as favoring increased emphasis on (1) basic, and (2) economic weed research; and furthermore that state and federal agencies be encouraged to develop specific research projects on basic studies and weed control costs and benefits, and that copies of this resolution be sent by the Secretary to the Agricultural Research Service, USDA and to state and territorial agricultural experiment stations.

The Committee moved that the fifth resolution be referred to the newly elected Executive Committee for their study and if they deem it appropriate that it be submitted to the Weed Society of America for action prior to or at their next meeting.

5. Whereas the Weed Society of America has become a well established and recognized scientific organization with its own technical journal, and Whereas the study and control of weeds has become the full time vocation of a large number of competent scientists, and
   Whereas this discipline has reached that stage of maturity that persons originally trained in various of the older sciences now consider themselves primarily specialists in weed control with common interests and objectives, and, Whereas there are several important industries wholly or partly based on weed control, and
   Whereas there is growing public recognition of the importance of weeds and weed control,
   Now, Therefore be it resolved that all members of the Weed Society of America shall actively work for the establishment and enhancement of a separate and distinct discipline by an appropriate name;
   Be it further resolved that this name shall be applied to all areas dealing with weeds and their control and that all persons whether in the research, teaching, or extension phases be considered contributors to this discipline.

Necrology:

Whereas, since our meeting 2 years ago, death has taken some members of our Society whose contributions to various phases of weed control are well known and respected and whose absence will be keenly felt,

Now therefore be it resolved that our expression of sorrow over their loss and of our sympathy to their immediate families be included in the records of this Society. The names we have are these:

Roland P. Borden, Formerly with New Jersey Power and Light Company

P. J. Buch, Formerly with American Telephone and Telegraph Company
E. F. Cottier, Formerly with Pacific Coast Borax Company
W. P. MacDonald, formerly with F. H. Peavey and Company

D. E. DAVIS
R. D. SWEET
F. L. TIMMONS
LAWRENCE SOUTHWICK, *Chmn.*

News and Notes

Edwin A. Davis has been appointed by the Crops Research Division, ARS, USDA, to conduct physiological studies related to control of chaparral in cooperative work with the U. S. Forest Service. Davis will be headquartered at Arizona State College, Tempe, Arizona.

Harold D. Kerr has been transferred from Columbia, Missouri, to Pullman, Washington, where he will be associated with W. C. Robocker in research on the control of rangeland weeds. The work is cooperative between the Crops Research Division, ARS, USDA, and the Washington Agricultural Experiment Station.

The Idaho Weed Control Conference was held March 13, 14 and 15, 1958, at Moscow, Idaho. The meeting was sponsored by the Idaho Noxious Weed Association and the University of Idaho.

Russell Nash, who was formerly stationed at North Platte, Nebraska, has been promoted to Chief, Weed and Seed Division, Nebraska State Dept. of Agriculture and is now stationed at Lincoln, Nebraska. He replaces Dwight Lambert who resigned to enter private industry.

Garvin Crabtree recently completed his Ph.D. degree in the Department of Vegetable Crops at Cornell University. He has accepted a position in the Horticulture Dept., Oregon State College, Corvallis, where he will be doing research on weed control in vegetable crops.

Earl Spurrier accepted a position with the Monsanto Chemical Co., St. Louis, Mo., in which he will be concerned with sales development work, particularly with herbicides. He was formerly extension specialist in weeds at the University of Illinois.

The 4th British Weed Control Conference will be held at the Hotel Metropole, Brighton, Sussex, England, from November 3 to 6, 1958. The program will consist of twelve sections dealing with various aspects of weed control.

R. F. Carlson will return to the Dept. of Horticulture, Michigan State University, East Lansing, to continue his studies on weed control in small fruits. For the past two years he has been working at the University of Ryukyus in Okinawa.

Ben Roche has been appointed Extension Weed Specialist in the Dept. of Agronomy, State College of Washington, replacing Henry Wolfe who was promoted to a supervisory position.

L. J. Klebesadel has assumed responsibility for weed control work in forages among other duties, at the Alaska Agr. Expt. Station, Palmer. Klebesadel started work at the Alaska Station after receiving his Ph.D. degree from the University of Wisconsin in 1957.

The Western Weed Control Conference elected R. A. Fosse,

American Chemical Paint Co., Denver, Colorado, president; W. R. Furtick, Oregon State College, Corvallis, vice president; and E. E. Heikes, Montana State College, Bozeman, secretary-treasurer at a recent meeting held in Spokane, Washington.

Ralph Gantz has accepted the position of Extension Weed Specialist with the Dept. of Agronomy, University of Illinois, Urbana. He completed his work for the Ph.D. degree at the University of Illinois in 1958.

Donald C. Nelson, formerly Research Asst. in Horticulture at the University of Minnesota, St. Paul, has been promoted to Research Fellow to conduct research on vegetables grown for processing. For the present he will devote his efforts to weed problems and to weed control research in peas, asparagus and sweet corn.

James A. Wilkerson has been appointed to the field of development staff of the agricultural chemical department of the Naugatuck Chemical division, U. S. Rubber Co., and will be assigned to the Pacific Northwest area. Wilkerson was previously a weed control specialist in the Botany Dept. of the University of California and located at the U. S. D. A. Cotton Field Station at Shafter, California.

The Ninth Commercial Spray Applicators' Short Course was held in conjunction with the State Weed and Pest Control Conference at Miller, South Dakota on March 19 and 20, 1958. The short course attracted commercial applicators, industry representatives, county agents and others interested in control of weeds.

SUSTAINING MEMBERS

American Chemical Paint Co., Ambler, Pennsylvania
American Smelting & Refining Co., Central Research Laboratories, South Plainfield, New Jersey
Asplundh Tree Expert Company, Jenkintown, Pennsylvania
Association of American Railroads, Chicago, Illinois
Chemical Insecticide Corp., Metuchen, New Jersey
Chipman Chemical Company, Bound Brook, New Jersey
Crag Agricultural Chemicals Division, Union Carbide Chemicals Co., White Plains, New York
Deere and Company, Product Research Dept., Moline, Illinois
Diamond Alkali Company, Cleveland, Ohio
The Dow Chemical Company, Midland, Michigan
E. I. duPont deNemours & Co. Inc., Grasselli Chemicals Dept., Wilmington, Delaware
G. L. F. Soil Building Service, Ithaca, New York
Geigy Agricultural Chemicals, Div. of Geigy Chemical Corp., Yonkers, New York
General Chemical Research Laboratory, Allied Chemical & Dye Corp., Morristown, New Jersey
Hercules Powder Company, Wilmington, Delaware
International Harvester Company, Chicago, Illinois
Miller Chemical & Fertilizer Corp., Baltimore, Maryland
Monsanto Chemical Company, St. Louis, Missouri
National Aluminate Corp., Chicago, Ill.
O. M. Scott & Sons Company, Marysville, Ohio
Reade Manufacturing Company, Inc., Jersey City, New Jersey
Spraying Systems Company, Bellwood, Illinois
Stauffer Chemical Company, New York, New York
Swift and Company (Plant Food Division), Chicago, Illinois
Thompson-Hayward Chemical Company, Kansas City, Missouri
United States Borax and Chemical Corp., Los Angeles, California

BIBLIOGRAPHY OF WEED INVESTIGATIONS
for
July, August, September, 1957

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Prepared By

UNITED STATES DEPARTMENT OF AGRICULTURE

Agricultural Research Service

Crops Research Division

This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Crops Research Division, Agricultural Research Service, U.S.D.A. does not assume responsibility for the subject matter cited.

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